PAPER

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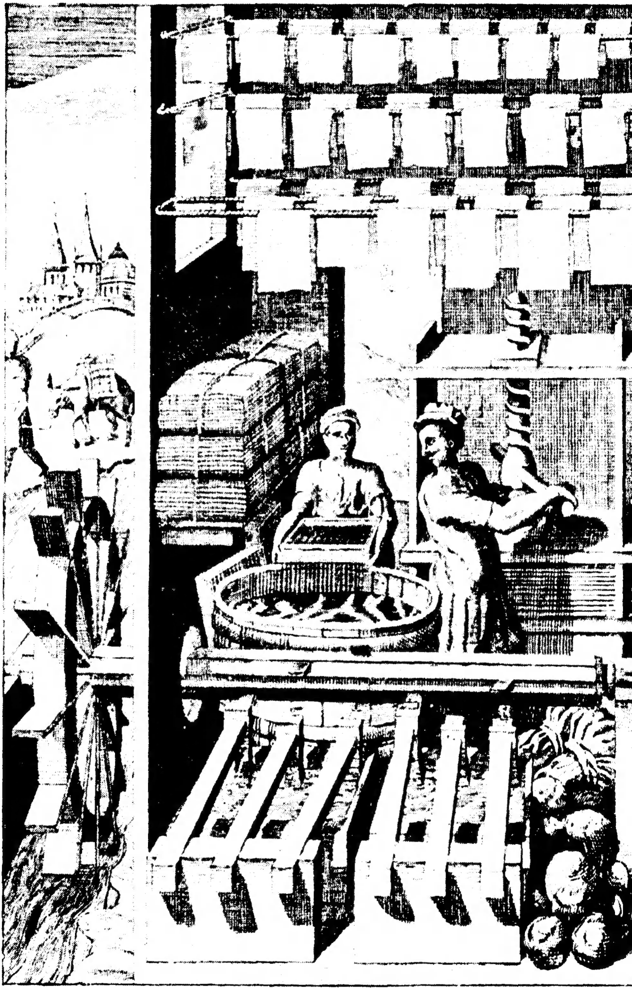

AN OLD PAPER MILL, A.D. 1662

(1465D) *Frontispiece*

PITMAN'S COMMON COMMODITIES AND INDUSTRIES

PAPER

ITS HISTORY, SOURCES, AND MANUFACTURE

BY

H. A. MADDOX

C. AND G. SILVER MEDALLIST PAPER-MAKING; AUTHOR OF "WHAT A STATIONER OUGHT TO KNOW ABOUT PAPER," "ACCOUNT BOOKBINDING," "PRINTING," ETC.

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PREFACE

THE purpose of this work is to place before those interested a popular handbook which will be sufficiently comprehensive to provide a thoroughly good insight into, and understanding of, paper and its manufacture. With the rapid extension of facilities for technical education in paper-making and allied processes, it is particularly desirable to cater to the needs of the student, the apprentice and the younger end of industry. While primarily written for those concerned in making, handling, or using paper, it has been the author's endeavour throughout to arrange and modify the language in order to render the subject intelligible to the general reader, whose knowledge of technical or trade terms and formulae is naturally less extensive. To the same end, considerable help has been afforded by the illustrations of machinery and methods, for which the author freely acknowledges his indebtedness to the following houses: Bentley & Jackson, Ltd.; Bertram's, Ltd.; J. Bertram & Son, Ltd.; E. Grether & Co.; W. D. Edwards & Son, Ltd.; H. B. Legge & Co.; J. Marx & Co.; Masson Scott & Co., Ltd.; Mather & Platt, Ltd.; T. J. Marshall & Co., Ltd.; The Mirrlees Watson Co., Ltd.; *The Paper Trade Review*.

HARRY A. MADDOX.

MANCHESTER.

CONTENTS

LIST OF ILLUSTRATIONS

PAPER

CHAPTER I

HISTORY OF PAPER MANUFACTURE

To survey the history of paper-making, it is necessary to go back some thousands of years to the time when the records of the nations were maintained in the monumental form of carvings on rock and stone. Of these, the earliest traces known are those of the early Persians, dating from eight to ten thousand years B.C. Later, stones, slabs, brass, bronze, and ivory plates constituted the medium by which man communicated to man his thoughts, records, and writings. A further link in the chain of transition from rocky cliffs to paper fabric comprises the beeswaxed board to which the early Egyptians transmitted their records by incision with the stylus. The incisions were afterwards filled in with earthy colour for the sake of distinctness and durability. Plain wood tablets were also used, the writing being performed in ink, or with charcoal, on a chalked surface.

About the period 4000 B.C. tile and clay tablets, cylinders, and cones were employed as writing material by the Assyrians and Chaldeans. Many of these records have been discovered by excavating parties in recent times, particularly in the pyramids. The characters were impressed on the clay whilst plastic, after which the clay was sun-dried or baked in an oven.

At a still later period, reptile and animal skins, cured and prepared on one side only, were put to use

in the form of small strips hollowed out and smoothed over. The writing was performed in the incised portion, and a lid was afterwards fitted in the hollow. This idea may be regarded as the forerunner of the modern envelope.

Contemporary with the use of these various materials, palm leaves were employed as the recording medium in various parts of China and Tibet.

The art of paper-manufacture was kept in secret by the Chinese for several centuries, but towards the close of the seventh century, as the result of a raid by Moors and Arabs, some Chinese paper-makers were taken prisoners, and presumably they imparted sufficient knowledge to their captors to enable the latter to introduce the art at Samarkand about the year A.D. 704.

It is usually asserted that cotton was the material employed in the manufacture of paper by the Arabs, but later evidence points to linen as the more probable material.

Paper-mills were established at Bagdad in the year A.D. 795, and for nearly five hundred years the industry was maintained as a State monopoly, the secrets of the process being carefully guarded. In later years, the industry fell into decline at Bagdad, but it was maintained in a flourishing condition at Samarkand, the thin, smooth, silk paper here produced being famous throughout Persia. Though designated silk paper, it was prepared from linen. In the eleventh century, the Moors introduced the manufacture of paper into Europe, Toledo (Spain) being the first place to receive the art. From Spain the process was carried into Italy, thence to France and the Netherlands. Between the thirteenth and fourteenth centuries the art of watermarking was invented in Italy, a discovery which added greatly

to the popularity and interest in paper. Incidentally, the introduction of watermarking was a factor destined to aid greatly the accuracy of historical research in all succeeding ages.

In A.D. 1336 the first paper-mill was erected in Germany, followed some time afterwards by a mill famous in the history of paper-making as Stromer's Mill. Ullman Stromer was a merchant of Nuremberg who, in the course of his trading, made journeys to Northern Italy. It is probable that in these travels he became acquainted with the craftsmen of Italy and conceived the idea of introducing paper-making in his native city. However that may be, he commenced to make paper on his own account in the year A.D. 1390 in the city of Nuremberg. His workmen were mainly Lombardian, as is evidenced from documents preserved to the present date. From these records, it is found that Stromer bound his workmen to secrecy under oath, and secured from each and every one of his employees a bond of fidelity. The first year of trading, however, brought serious labour difficulties and Stromer had recourse to the mediaeval justices, who upheld the manufacturer and consigned his unruly workers to prison. The incident served its purpose, for, on release, the recalcitrants swore renewed faithfulness, and kept their pledges so well that Stromer enjoyed the profits of his ability down to the year A.D. 1407.

From Germany the art of paper-making found its way to Switzerland, thence to Holland (which country speedily became renowned for the manufacture of excellent papers), and finally to England. The Revocation of the Edict of Nantes is generally mentioned in bibliographical history as being the occasion of the emigration of a large number of French paper-makers to Holland, Germany, and England.

Mention of one of the earliest paper-mills in England is made in the Colophon of "De Proprietatibus Rerum," printed at Westminster by Wynkyn de Worde, A.D. 1496, the lines referred to reading—

> And also of your charyte call to remembraunce
> The soule of William Caxton first prynter of this boke.
> In laten tongue at Coleyn hyself to avance
> That every well disposed man may theron loke.
> And John Tate the younger, Joye mote he broke,
> Which late hath in Englonds doo make this paper thynne
> Which now in our englysch this boke is prynted inne.

The John Tate the Younger referred to was the son of a Lord Mayor of London, and he erected the Sele Mill, at Stevenage, Hertford. The accounts kept for King Henry VII record that on 25th May, 1498, the sum of 16s. 8d. was given as a "rewarde" at the "paper mylne." In the following year, a further 6s. 8d. was given as a second "rewarde."

Some of John Tate's papers were watermarked with a five-pointed star, extant specimens of which are to be seen in some of the books printed by Wynkyn de Worde, Caxton's successor.

With the disappearance of Tate, paper-making appears to have fallen for a time into total disuse in England, although there are traces of an attempt to re-introduce the art in Cambridgeshire, about 1548, by a foreigner, Rémy, under the influence of Thomas Thirlby, an English bishop.

In the year 1588 Spielman brought a knowledge of the process from Germany and, obtaining from Queen Elizabeth a ten years' licence, he erected a mill at Dartford, in Kent. In 1601 and 1602 he took legal actions against John Turner, Edward Marshall, and George Friend, who had commenced paper-making operations in Buckinghamshire. His efforts appear to have been successful, for in the year 1605 James I

visited his mills and Spielman became a knight. Meantime, Marshall had received permission to make paper on payment of a royalty to Spielman. The Dartford mill is only supposed to have made coarse papers, not white.

From the time of Spielman until 1641 paper-making again died out in England, and in the latter year a patent for the invention and manufacture of white paper was granted to Endymion Porter, Captain John Reade, Edward Reade, and John Wakeman. The civil wars of the period, the plague, and civic objections to paper manufacture and the collecting of rags contributed to the failure of this enterprise, and once again the art became neglected. In 1665 the first British patent was granted to one Hildegard for the manufacture of blue sugar paper, and in 1678 there is mention of a paper-maker, Eustace Burneby, Esq., but available information regarding his efforts is meagre. Onward from 1678 paper-making began to be firmly established in England, and the number of makers increased. The year 1685 saw a great influx of Huguenot refugees, among them being many highly-skilled paper-makers. In this year also John Briscoe took out an English patent for "The true art for making as good paper as French or Dutch."

The next incident of note in the history of paper-making in England is the advent of Whatman, the famous paper-maker of Maidstone, Kent. Whatman learned the art in Holland, to which country he had made many journeys in the course of his business. In 1760 he built a mill at Maidstone and commenced to set up a reputation for the manufacture of high quality papers. With each succeeding year the Whatman papers grew in renown, and to assist him James Whatman took into his service William Balston, who succeeded him on retirement in 1793. At the present

day papers with the Whatman watermark from the Maidstone Mills (made by the old hand-made process), still associated with the name of Balston, are, without doubt, the most well-known and highly esteemed papers in the world.

The first paper-mill in America was commenced in 1690 by William Rittenhouse, at Roxborough, Philadelphia. Rittenhouse was born at Amsterdam, but, in later life, emigrated to the States and became an American subject.

Until the close of the eighteenth century paper-making was mainly a hand process, at least so far as the actual formation of the sheets was concerned. In the year 1798 Nicolas Louis Robert, formerly a printer's reader in the employ of Francois Didot, and afterwards a clerk inspector in the Essonnes Paper Mills, belonging to St. Leger Didot, invented a machine for making paper in lengths of 12 to 15 metres. A year later, the first effort to turn out paper on the new model was made at the Essonnes Paper Mill. The French Government had meantime subsidised Robert in his endeavours to a small extent, and had granted a fifteen years' patent. The state of France, with the Revolution just subsiding, was hardly conducive to the success of new industrial enterprise, and, consequently, little or no headway was made with the machine in that country. Being in financial difficulty, Robert sold his patent to Didot for 25,000 francs, to be paid in instalments. The payment was so slow, however, that Robert recovered his patent on 23rd June, 1801. Meantime, in 1799, Didot proposed to his brother-in-law, John Gamble, an Englishman, to take up the capitalization of the patent in England. With this object in view, Didot, in 1800, crossed the Channel (although at this period France and England were at

enmity) and came into touch with Henry and Sealey Fourdrinier, two prosperous London stationers, whose sympathy in the idea of the paper-machine had been enlisted by Gamble. An English patent was taken out and the services of a capable and ingenious engineer (Bryan Donkin, of Hall's Works, Dartford) were engaged for the production of the first English paper-making machine. In 1803 machines were set in motion at Frogmore Mill, Two Waters, Hertfordshire, and the St. Neot's Mill, under the supervision of John Gamble. Gamble had taken out two patents on the machine, one in 1801 and another in June, 1803, both of which he assigned to the Fourdrinier Brothers in 1804. Having lost heavily as a result of his enterprise, Gamble, in 1808, turned over the whole of his interest in the machine, and the Fourdriniers were left to continue the development of the patent. The seven years' patent originally granted to Gamble expired in 1807, and, with the object of extending the period to fourteen years, an appeal was made to the Government. Although passed in the Commons, the Bill was rejected by the House of Lords, on the ground that the Fourdriniers were not the original inventors. Thus, having expended the whole of their private fortune (some £60,000 it is supposed) in the improvement of the machine, they became bankrupt, went out of business, and ultimately died almost without means, a small allowance being granted to Henry from a fund raised by *The Times*.

In 1809 Mr. J. Dickinson (the founder of the present firm of Messrs. John Dickinson & Co., Ltd.) invented the Cylinder paper-making machine, and in 1821 drying cylinders were added to the Fourdrinier machine. Before this date the Fourdrinier contained no suction apparatus or drying arrangement, hence the paper was reeled in a wet state, necessitating cutting in sheets for loft-drying.

CHAPTER II

THE EVOLUTION OF PAPER-MAKING

In the early days of printing, when Gutenberg, Fust and Schoeffer, and later Jenson and Caxton, practised, the hollander, or beating engine, was unknown to paper-makers. Rags were reduced to pulp in very elementary fashion. At the inception of paper-making the following was the method adopted. The material was gathered together and allowed to ferment, then boiled in wood ashes and put into bags which were immersed for a considerable period in a running stream. Having thus removed the alkaline residue and a large proportion of the dirt, the mass was beaten, 2 or 3 lb. at a time, on wooden blocks, with heavy sticks. By this process the material was gradually reduced to a pasty pulp, which was diluted with water to the required consistency. Sheets were formed by immersing in the pulp a rectangular sieve, with meshes formed of strips of bamboo or similar material connected together by silk threads. The pulp was contained in a vat, and was constantly stirred during the making of the sheets. Sufficient fibre to form a sheet was picked up on the sieve and the drying of the sheets was afterwards performed by exposure to sun and air.

With but slight variation, these were the methods introduced and employed in Europe up to the invention of the stamping mill in A.D. 1151, at Xatina (an ancient city of Valencia), Spain. This apparatus superseded the original practice of pounding the material to pulp with the pestle and mortar. At this period therefore the process of paper-making may be described as follows:

Rags alone were used so far as Europe was concerned, cotton and linen forming the staple material. The rags were first wetted, then squeezed into balls and left in a heap to ferment for about six weeks, during which period they were moistened and turned from time to time. The tender and partly retted rags were then submitted to the action of the stamping mill (*see* frontispiece), this process accomplishing in a crude manner the work which at a later period was more efficiently performed by the hollander. The stamping rods or pestles consisted of long wooden bars, which were actuated by wooden pallets on a shaft revolved from a cog-wheel. The pallets caused the rods to be raised up and dropped with considerable force into the trough containing the rags and water. The whole contrivance was worked by water power. An improvement was effected by means of which the stamping-rods were shod with nails, graduating in fineness as the pulp progressed through the various troughs or pans. These pans were lined with iron or brass, and in the foremost mills the pulp passed through as many as six pans, each containing three stampers. Circulation was kept up and a stream of clean water was maintained through the pans, the dirty water escaping through a horsehair mesh. The process was naturally slow, forty pairs of stampers requiring one day and night to accomplish the maceration of 1 cwt. of rags. After sufficient pulping, the sheets were formed in a manner very similar to that by which hand-made paper is made to-day Before 1755 all papers were made on a laid mould, woven wire moulds not being invented until that year, when they were introduced by Baskerville, the English printer. After the waterleaf sheets had been formed, they were passed along to the coucher, who, when he had obtained 6 to 8 quires interspersed with felts,

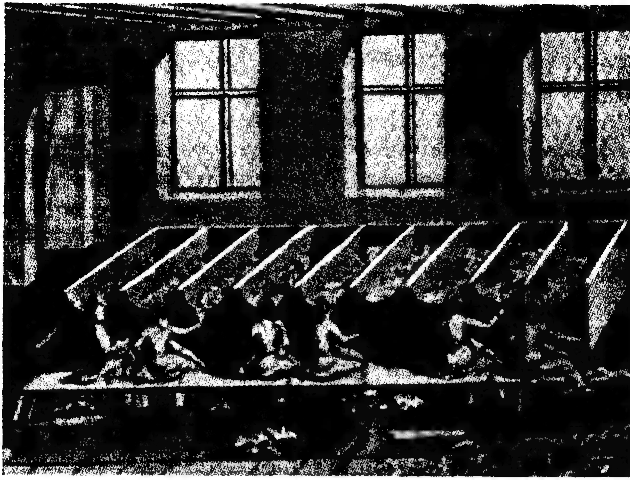

FIG. 2. RAG-SORTING PROCESS
(Old print)

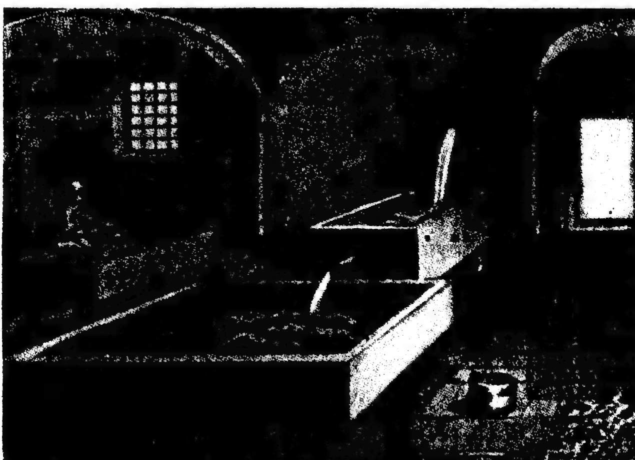

FIG. 3. RAG-WASHING PROCESS
(Old print)

pressed them in a screw-press. They were afterwards re-pressed without felts and hung to dry in batches of four or five sheets. Following this, the sheets were sized with the extract of raw hides, and again dried and pressed for twelve hours. To obtain a smooth finish, constant pressing, hammering, or rubbing with flint was resorted to.

At a date variously ascribed between 1690 and 1720, the hollander, or beating engine, was invented by the Dutch, and gradually it superseded the stamping mill. The hollander consisted of an oval-shaped wooden trough, with a division running lengthway along the centre. At one side was fixed a wooden, revolving cylinder fitted with steel knives, which worked against a bed-plate also containing knives. The revolutions of the cylinder caused the material to pass through the knives and round the trough, the midfeather or centre division (which was of such a length as to leave a passage at the ends of the trough) compelling the pulp to make a complete and continuous circuit. A few hours in the hollander sufficed to reduce the toughest material to a state of pulp.

Shortly after the hollander, rollers for glazing were introduced in the same country, and the old flint rubbing gradually became an almost obsolete process. Later inventions and improvements in the making of paper include the discovery of chlorine, in 1774, by Scheele, the bleaching action of chlorine gas, in 1785, by Berthellot (a Frenchman), soda-ash, by Leblanc, in 1791, and the introduction of bleaching powder, by Tennant of Glasgow, in 1800. In 1807 Moritz Illig, the son of a German clock-maker, introduced resin for the sizing of paper pulp. The full details of practical treatment and an account of the chemical actions involved in the process were set forth in a pamphlet

entitled, *The Process for Sizing Paper in the Pulp during the Process of Manufacture,* Illig, Erbach, Frankfort A/M, 1806.

Strainers were used on the paper-making machine in the early 20's, the first authentic date being 1821, when a paper-maker of Poyle, Middlesex, one Richard Ibbotson, took out a patent for a self-cleaning strainer.

In 1826 the first dandy-roll was made by Marshalls' of London for Towgood's mill. Probably this was the same mill that saw the introduction of the Fourdrinier paper-making machine, for Mr. Matthew Towgood, in 1808, took over the St. Neot's Mill from the Fourdriniers.

Mechanical wood-pulp was commercially introduced by Gottlieb Keller, a German, in 1840.

An Englishman, Routledge, was the discoverer of esparto grass as a paper-making material in 1860.

In 1856 Perkins, the English chemist, made discoveries which brought coal tar (aniline) dyes into being.

In 1866 Tilghmann found the possibilities of sulphurous acid and bisulphites for boiling wood-pulp; but it was Mitscherlich who perfected the process of sulphite pulp-preparation in 1874.

CHAPTER III

CELLULOSE AND ITS COMPOUNDS—THE CHARACTERISTICS OF FIBRES

In order to understand intelligently the process of paper-making, it is necessary to know something of the basis of paper construction. Paper may be described as an aqueous deposit of vegetable fibre or as a fabric composed mainly of minute vegetable fibres which have been deposited on to a sieve-like structure from their suspension in water, and commingled and felted together in such a manner as to form a homogeneous sheet or web. The basis of paper is cellulose, and it is cellulose that forms the substantial part of plant tissues. Considering plants as being constituted of fibres and cells, the former may be taken as representing the cellulose or available material for paper-making, while the latter represent an undesirable element which requires to be eliminated as a preliminary operation in the routine of paper manufacture. In the case of rags or manufactured textiles, which constitute a valuable source of raw material for the paper-maker, the eliminating process is already partly performed by the textile manufacturer, who, like the paper-maker, is mainly concerned with the fibrous element. In the case of such types of raw material as wood, straws, esparto, and the like, the removal of the non-cellulosic matter and the production of relatively pure fibre must be performed in the pulp or paper-mill. For this purpose the usual routine includes chemical boiling under pressure, washing and bleaching, etc.

Cellulose, then, is to be regarded as the framework of plant organism. Chemically, it is a carbohydrate,

with the empirical formula $C_6 H_{10} O_5$ the precise formulae not yet having been definitely ascertained. Although it is stated that cellulose is the basis of paper, it must not be taken that the fibrous materials employed in the making of paper are chemically pure cellulose. As a matter of fact, there are three types of cellulose employed, cotton representing the pure cellulose, flax being typical of the pecto-cellulose, wood and jute belonging to the ligno-cellulose group, while all fibres embody in their composition a more or less small percentage of fat, wax, mineral matter, lignin, etc.

Cotton is regarded as the prototype of the celluloses. In nature it occurs as a mass of fibre without the accompaniment of non-cellulosic matter, save for almost negligible traces of foreign substances incorporated during growth. The purity of cotton cellulose accounts for its use in the manufacture of gun-cotton for high explosives. Until the later stages of the Great War the impurity and complex nature of wood cellulose constituted a difficulty which debarred its use for this purpose.

Cellulose is amorphous; in other words, it is incapable of crystallisation by any known method. It is also insoluble in all simple solvents, while toward the action of most reagents it is comparatively inert. To these properties, cellulose owes its remarkable value as a paper-making material. By reason of its inertness, it becomes possible to remove the combined foreign matter without much danger of attacking the cellulose itself. For this purpose various alkalis are used, by methods explained in a later chapter.

Certain solvents of cellulose have been discovered, however, and now receive wide application in the industrial world. Thus, zinc chloride in hot solution will dissolve cellulose to yield a viscous compound. This process is applied in the manufacture of vulcanized

fibre and in the production of filaments for incandescent lamps. Ammoniacal cupric oxide (technically known as Schweitzer's Reagent) is also a solvent of cellulose, and is used in the manufacture of the well-known waterproof Willesden canvas and paper. Schweitzer's Reagent, or modifications of it, has been employed more recently in the production of artificial silk, the cellulose being dissolved and forced at high pressure through orifices in the form of extremely fine threads, which, by dilute acid treatment, are fixed and solidified.

Cellophane, the transparent form of wrapping, is produced from viscose, a dissolved state of cellulose treated with carbon disulphide.

Under exceptional conditions, cellulose becomes susceptible to the action of agencies employed in the normal routine of mill work. The two compounds which cellulose is capable of forming and which more seriously concern the paper-maker, are oxy-cellulose and hydra-cellulose. The former is, as the name implies, a result of oxidation, oxygen from the atmosphere being induced to enter into chemical combination with the cellulose molecule. The action most readily takes place during the bleaching process. Bleaching solution is apt to set up oxidation if the action is allowed to take place under exposure to the air and sunlight, or if the temperature at which the process is conducted reaches too high a standard. Oxy-cellulose has the peculiar property of assuming deeper shades in contact with basic dyes, whilst with certain other types of dye lighter shades are produced. In addition, oxy-cellulose renders the ultimate paper weak and brittle, whilst the colour or whiteness speedily deteriorates.

Hydro-cellulose is a result of hydrolysis, or the chemical combination of water with the cellulose. It is formed in several ways, as by the action of weak acids

or alkalis, or by the action of a series of ferments known as Enzymes. The hydration of cellulose is a different type of action, commonly met with and aimed at in the production of grease-proof and similar papers. In this case, the material is beaten in such a manner and for such a period of time that the fibres become incorporated with the water and take on a sort of gelatinous coat or film. By this means, strength, toughness, and rattle are aided, but the look-through of a paper is deteriorated, the last factor being of little importance in the class of paper produced by this treatment. The product is termed hydrated cellulose.

The essentials in any paper-making raw fibrous material are embodied in the following considerations. It should be procurable in sufficient and continuous quantity at a competitive price; a relatively large yield of fibre embodying the requisite character should be attainable; the process of eliminating foreign matter and converting the material into relatively pure pulp should be reasonably free from difficulty and expense under ordinary methods of manufacture. Transport facilities should be adequate, readily available, and reasonably cheap. The materials in present employment for the production of paper include threads, rags, textile cuttings of all kinds (save those of animal origin), bagging, untarred rope and string, wood, straw, esparto, manilla hemp, and, in small quantity, bamboo, sugar-cane, and a few newly introduced plant substances.

The physical structure and properties of the ultimate fibres are primarily responsible for the character of the paper produced therefrom. The boiling and beating operations may to a very large and growing extent control the ultimate character of the paper; but, notwithstanding the advance that has been and may yet be made in these directions the fact still remains that

the primary character of the individual fibres is reflected in the finished paper. No amount of care and manipulation in the preliminary processes can induce an inferior fibre to yield pulp equal in value to that produced from higher class material. The fibre makes the paper, and the *modus operandi*, if rightly pursued, secures the full efficiency. It is therefore essential that the student or paper-maker should be well acquainted with the physical character of fibres, in order to appreciate their bearing on the finished sheet of paper. When the true character of the individual fibres is known, it is by no means a difficult matter not only to identify the various fibres and roughly assess their proportions in a sample of paper, but also to gauge the type of treatment undergone in the preliminary processes. For this purpose the aid of the microscope must be requisitioned.

It is necessary at this point to devote some little consideration to the subject of the microscope and its accessories, and the process of preparing the fibres, etc. For such investigations as the paper-maker is called upon to perform, an ordinary student's microscope, with fine and coarse adjustment, is sufficient. The equipment should include $\frac{1}{2}$ in. and $\frac{1}{4}$ in. objectives and lenses for magnification at low and high powers, say from 60 up to 300 diameters. The microscope should preferably be fitted with a double nose-piece to take the two objectives. For measuring fibres, a micrometer eye-piece with scale divided into $\frac{1}{100}$ mm. is necessary. Slides, 3 in. by $\frac{7}{8}$ in., and $\frac{5}{8}$ in. cover glasses, teasing needles, and mounting accessories, together with a bit of unglazed porous plate for draining fibres, filter papers for irrigating, and 1 per cent. caustic solution for separating the fibres will suffice to enable the student of paper-making to practise fibre microscopy.

The method of preparing fibres for microscope slides

is as follows. The sample of paper or material is boiled with the 1 per cent caustic soda solution in a test tube or evaporating dish for a longer or shorter period, according to the hardness of the sample. Filter or blotting paper would disintegrate in a very short time, probably without the caustic; but clay-coated or hard tub-sized paper would require much longer and stronger boiling. The aim is to reduce the sample practically to pulp. The contents of the tube are then poured on to a fine-mesh wire sieve (about 100 to the inch), the fibres which remain on the sieve afterwards receiving a thorough washing with cold water. To complete the disintegration and secure clean individual fibres, the pulp is removed from the sieve into a bottle containing pure water and a quantity (about ½ in. deep) of Bohemian garnets (the latter being procurable from any dealer in microscopes and accessories) and shaken up thoroughly until the desired object is attained. The liquor is then poured back through the clean sieve, and the fibres, which are now in a fit state for microscopical examination, are transferred to a watch glass or piece of porous plate. To prepare the slide, a mere spot of the fibre is placed in the centre of the slip and teased out with the needles so that no portions of the fibres appear clotted. A drop of distilled water may be necessary to aid the operation, but the fibres should not be flooded or they become uncontrollable. When the lay of the fibres appears satisfactory, a cover glass is placed in position (being careful to avoid air bubbles) and the surplus water sucked away from the edges of the glass by touching with filter paper. The specimen is then placed in position on the stage of the microscope and viewed first under low power, leaving the high magnification for later study.

To aid in the identification of the various classes of fibres, certain staining and chemical solutions are

employed, the consideration of which may be more appropriately undertaken after the characteristics of the fibres have been described.

Linen. The typical linen fibre is rounded or polygonal in section, the latter shape being more generally assumed owing to the fibres growing in bunches or

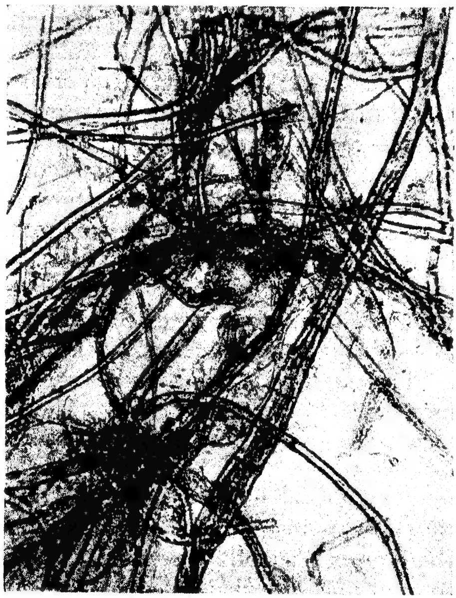

FIG. 4. LINEN FIBRES

filaments. Being tightly pressed together, the fibres lose their roundness and assume the hexagonal or polygonal shape. The natural ends of the ultimate fibre are gently tapered, but in the examination of treated fibres it is usually found that they have been severely squeezed and crushed, with the result that the

ends are split up into shredded fibrillae. Technically, the character induced by the beating process is termed lamination. A close examination of the linen fibre reveals a narrow channel or canal running in a regular manner through the centre, lengthwise of the fibre. This is technically known as the lumen, but the more generally accepted name for it is "canal." The fibre itself is fairly wide in diameter, hence it follows that, as the canal is very narrow, the side walls of the fibre must be rather thick. It is very important to note these characteristics carefully, for they are a distinct aid toward the correct identification of fibres. On close scrutiny it will be observed that many of the linen fibres bear peculiar markings. Some show creases, or cross-markings, the result of bending; others show nodes or joints like a miniature bamboo. The illustration clearly presents one of these nodes with a perfect double cross-marking. Before treatment for paper-making purposes, linen fibres frequently contain a number of bulbs. During the breaking and beating processes, the bulbs often become burst or cut. The illustration presents examples of the unscathed bulb as it appears under the microscope.

Cotton. The cotton fibre, which stands as the prototype of paper-making fibres, differs very materially from other types excepting certain chemical wood-pulp fibres. Under the microscope, the true cotton fibre appears flat and ribbon-like, with rounded side-walls and a conspicuous canal. Obversely to the linen fibre, the lumen being large, the side-walls are relatively thin. During growth, while the nutriment is passing through the fibres, the latter are naturally round, and, occurring singly, they are not subjected to the pressure which filaments sustain, hence, in section, they do not attain the polygonal shape peculiar to linen and other

filament fibres. Apart from the plant, however, they endure the drying process, which causes the individual fibres to collapse on their axis and assume the above-mentioned flattened shape. As the fibre collapses, it generally assumes a number of twists along its length, as shown in the illustration, which was photographed

FIG. 5. TYPICAL TWISTED COTTON FIBRE

under high magnification. The canal and its markings are also quite distinct, while the relative widths of the canal and side-walls afford a good study. The sunken area between the rounded sides often exhibits slight cross-markings, striations, or granules. The ultimate cotton fibre, like that from linen, is very long in comparison with other fibres, therefore a certain amount of mutilation and distortion must be allowed for in the beating and other processes. It is often very difficult,

even with the aid of colouring solutions, to identify well-beaten cotton fibres from linen.

Esparto. The esparto fibre represents a type of material more highly esteemed in Britain than elsewhere. Under the microscope, the typical esparto

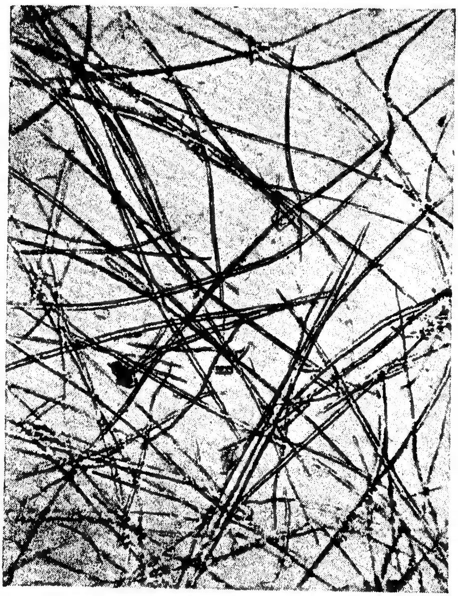

FIG. 6. ESPARTO FIBRES AND CELLS

fibre appears as a thin, smooth and short fibre. In section, it is seen to be almost round, with a very narrow central canal. The canal is visible up the length of the fibre, and it runs along very regularly. Although so narrow, the fibre, when viewed under high magnification, is seen to exhibit traces of cross-markings, somewhat

similar, but not so distinct as those of the linen fibre. The ends of esparto fibres may be either blunt or tapered, but the latter shape is more general. Occasionally, bifurcated ends are to be observed. In a microscopic investigation, however, the decisive proof of the presence of esparto is not so frequently sought for in the fibres as among the accompanying cells. In both straw and esparto, a number of types of cells and other characteristics are met with, some general to both, others peculiar to one or the other. The typical and distinctive esparto cell is a minute seed-hair, shaped like a tooth or comma. The illustration shows several examples clearly. In the natural plant these cells are invisible hairs sitting on the stem. During manufacture of the pulp, although of no use to the process, a large number of these hairs find their way through, and ultimately take their place in the finished paper. Although absolutely peculiar to esparto, the finding of a solitary pear or tooth cell must not be taken as conclusive proof of the presence of esparto, for it is obviously possible that a few cells may remain at the bottom or on the sides of the beating engine after an esparto furnish has been removed. Taken in conjunction with the fibre and the presence of serrated cuticular cells, the establishment of identity is by no means a difficult matter. The serrated cuticular or epidermal cells are common to both straw and esparto, although they may differ in size and shape. Several are to be observed in the illustration, typified by corrugated or toothed edges, and a longer or shorter oblong shape. The hollow interior of the cells is usually granulated. The fact that esparto fibres are so short and narrow helps identification, as they usually escape mutilation by the beater knives, and thus appear fairly typical under the microscope. Again, apart from being so small, they

are usually selected for grades of paper which are treated in a free manner, as in the case of body stock for chromo and art paper. There is thus always the certainty of coming across representative fibres.

Straw. The straw fibre is somewhat like esparto, but is shorter and thicker, frequently exhibiting sharp bends and creases. The fibre is not so flexible as esparto, hence, the bending produces what may be termed a

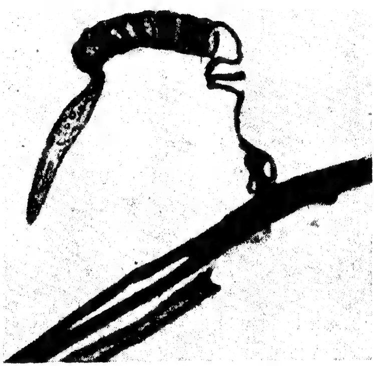

FIG. 7. FIBRES AND CELL FROM STRAW PULP

kink. The ends are tapered gradually. Straw pulp contains a large number of cells, but does not show any cell similar to the pear cell of esparto. There is, however, an equally peculiar and characteristic feature, known as the spiral cell. This occurs in no other pulp with the exceptions of bamboo and bagasse. The cell may occur as a complete spiral, or as a simple ring, the latter representing an isolated detachment from the former, occasioned by the beating process. A spiral cell is shown on the accompanying photo-micrograph.

Another characteristic type of straw cell is the parenchymatous or voluminous cell, which takes the form of a transparent oval or adjoined ovals linked together like saveloys. These cells are derived from the pith which lines the straw stems. They occur also in bamboo pulp. As a rule they are pitted with fine pores, hence they are sometimes known as perforated cells. The serrated epidermal cells mentioned in the case of

FIG. 7A. VOLUMINOUS CELL FROM STRAW

esparto are also present among straw fibres, and are very similar in contour, but differ considerably in size, according to the class of crop from which they are derived.

Jute. Jute represents the typical ligno-cellulose fibre, being of a woody nature. Under the microscope, the side walls of the fibre appear thick and the lumen or canal is very irregular. This widening and narrowing of the lumen is a very characteristic feature of jute. The fibre usually exhibits cross-markings, nodes, joints and striations parallel with the fibre. The cross-markings particularly are very distinct and numerous.

The ultimate fibre is very much shorter than rag fibres, but is about half as long again as straw or esparto. The ends are spear-shaped and show an appreciable widening of the lumen. Jute may be readily distinguished from rag fibres by means of the colour reactions which will presently be described. It is advisable to study the diversions of the lumen of the jute fibre under the influence of a colour stain which brings all features into prominence.

Bamboo. This material belongs to the same order as straw and, although not largely employed in present paper manufacture, is a subject of discussion owing to its immense possibilities. Under the microscope, bamboo fibres and cells closely resemble those from straw. The fibres are thin, smooth, round, and pointed at the extremities. Elongated and squat oblong cells (parenchyma) abound in the pulp, and, like those of straw, they are finely perforated. Occasional narrow, perforated cells and spirals or rings are met with.

Manilla. The manilla fibre is one of the strongest used in paper-making. Before treatment it is very long, hence the specimens from finished paper are usually cut up and lacerated. Its width or diameter is about equal to linen. The side-walls of the fibre are thin, uniform, and well defined, leaving the canal distinct and fairly wide in relation to the fibre. Cross-markings are frequently met with, but no nodes or joints such as are seen on linen fibres. Oblong parenchymatous cells are present in continuous series, having something of the appearance of a built wall. Occasionally they occur singly or in small groups.

China Grass, or **Ramie,** is a very long transparent fibre, with a width averaging twice that of cotton. Under the microscope, it appears very irregular, as a rule, bearing longitudinal markings or fissures (striae) which

frequently curve upwards in a slanting direction. Occasional smooth fibres occur with narrow canal and cross-markings like linen. The canal is well defined and often contains granules, while the ends of the fibres vary, being either spatulated, spear-shaped, tapered or blunt-rounded.

At this stage the approximate dimensions of the fibres, according to authority, may be tabulated. They are as follows—

	Length mm.	*Breadth* mm.
Cotton	30	·025
Linen	25	·020
Jute	2·5	·022
Esparto	1·5	·012
Straw	1·5	·015
Wood (Coniferous)	3	·030
,, (Deciduous)	1	·020
Manilla	7	·020
China Grass	22	·050
Adansonia	12	·020
Bamboo	4	·015
Sugar Cane (Bagasse or Megasse)	3	·015
Paper Mulberry	12	·025

Wood Fibres. Wood fibres differ in physical characteristics according to their source, those from deciduous trees exhibiting markedly different features to those from the coniferous series. Generally speaking, wood-pulp fibres are somewhat similar to those from cotton (i.e. they are often flattened in shape, and in many cases embody a number of twists). The coniferous fibres are broader than cotton, on the average approximating to 0·030 mm.; deciduous fibres averaging ·020 mm. against ·025 mm. for cotton. The character of the twists on wood fibres is different from cotton. The twists of the former appear more like sharp folds than the corkscrew turns (occasioned by collapse) associated with the typical cotton fibre.

Wherever doubt exists as to the identity of a wood or cotton specimen, a decision can be reached by applying a colouring solution, as referred to at the close of this chapter.

Paper-making woods, for the purpose of microscopic study, may be considered as two classes, the coniferous

FIG. 8. PITTED VESSELS ON CHEMICAL WOOD

or cone-bearing series (typified by the pine, fir, and spruce), and the deciduous series (typified by the aspen, birch, and poplar). Under the microscope it is to be observed that the fibres from wood pulp of coniferous trees are entirely composed of tracheids, i.e. cells or fibrous tubes through which air passes. The pulp from deciduous trees is constituted by both fibres and vessels. Coniferous woods are softer than the deciduous woods used for paper-making and the ultimate fibres are longer. It must be observed, however, that, so far as the coniferous family is concerned, the length and shape

of the ultimate fibres is largely governed by the period of growth and formation. Thus, the spring and summer tracheids are broader and flatter, with thinner side-walls than the autumn and winter tracheids. In the case of the former, the ends usually appear blunted, while the ends of the autumn and winter tracheids are more inclined toward a spindle shape.

Coniferous tracheids exhibit characteristic pitted rings or circular pores, which are actually constituted by holes in the fibres.

Spruce wood is composed entirely of tracheids and yields a characteristic fibre. The shape is flat, ribbon-like, with occasional twists or folds. Concentric double ring-markings are generally to be observed, either oval or circular, also traces of parallel cross-markings between the rings. The latter feature is known as the medullary rays, being the connecting link between the pith and the bark of the growing tree.

Pine tracheids are very similar to spruce, but show single rings or ovals as well as those of the concentric type. Traces of the medullary ray lattice-markings are observable.

Poplar is composed of true woody fibres which, compared with spruce, are short, rounded and less ribbon-like. The side-walls are thick and show occasional nodes or joints, while the central canal, which is fairly wide, sometimes exhibits small oval pitted markings. The most interesting microscopic feature of poplar pulp is the presence of a large number of broad, thin-walled vessels. These vessels usually embody a pattern closely resembling lace, the markings occurring in the shape of pits or pores. As a rule, one end of the vessel is blunt, the other being shaped like a pointing finger. Each end shows a mouth, the construction of which serves to distinguish between pulps from American

or European grown poplar. In the case of European poplar, the mouth is open and plain, whereas the vessels from American poplar have a series of filaments strung across the mouth.

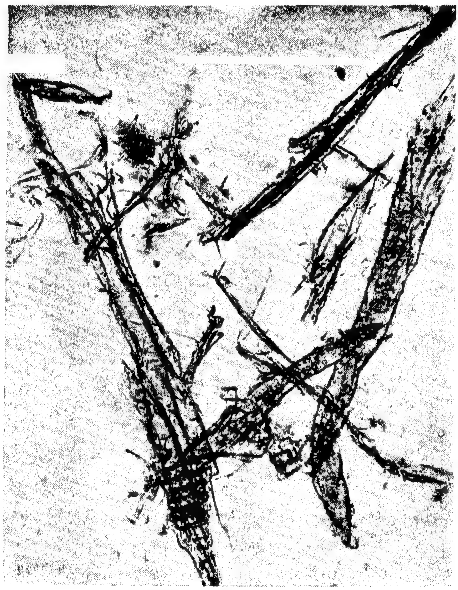

Fig. 9. MECHANICAL WOOD-PULP FIBRES

Birch pulp contains fibres and vessels closely resembling those of poplar in character. The fibres are, however, slightly longer and exhibit small oval pitted markings. The vessels are more distinctive than the fibres.

Mechanical wood-pulp is readily detected in paper by application of the staining solutions described in this

chapter. Under the microscope, the fibres appear as clumps, broken portions, mutilated fibres, and fragments of all descriptions. Medullary rays and circular pores (concentric or single) abound, and in many cases the former run across clumps of fibres or fibre fragments.

Colouring Stains and Solutions. Staining solutions are employed to emphasise the native characteristics and features of the individual fibres and cells. Unlike the chemical colour reacting solutions, the staining solutions establish no identity by colour reaction. Chiefly, dyes from the coal tar series are employed for the purpose of direct staining, the principal solutions being methylene blue, magenta, malachite green, eosine, and bismarck brown. The strength of solution equals about 1 in 2,000 parts of water. In use, the sample of fibre is teased out on the slide under moisture in the usual way, and one drop of colour stain applied. After allowing sufficient time for impregnation, the cover glass is affixed and the surplus liquor absorbed by filter paper. Through the microscope, it will be observed that decided prominence is given to such features as the lumen, striae, cross-markings, pores, etc.

The chemical colour reagents are of more importance than the staining solutions in establishing the identity of fibres. Not only do they bring into prominence the characteristic markings, but they also produce distinctive colours in the case of different fibre groups. The most distinctive and reliable reagents in use are the Herzberg solution, and the zinc chloride solution, known technically as the iodine in potassium iodide, and zinc chloride and iodine solutions.

The constituents and proportions in the former are—

Potassium Iodide	2 grammes
Water (distilled)	20 c.c.'s
Iodine	1·15 grammes
Glycerine	2 c.c.'s

The mode of application is exactly similar to that described for staining solutions. The chief thing is to avoid applying too much solution, which would simply darken the fibres and harass identification. The colour reactions of this solution on the various types of fibre are—

Brown Colouration.	*Yellow to Yellow Brown.*	*Colourless to Slightly Grey.*	*Grey to Brown.*
Cotton Linen Bleached Hemp	Unbleached Jute ,, Straw Mechanical Wood Pulp	Bleached Jute Manilla Hemp Chemical Wood Esparto Bleached Straw	Adansonia

The constituents of the zinc chloride solution are—

A. Solution.		*B. Solution.*	
Zinc Chloride	20 grammes	Potassium Iodide	2·1 grammes
Distilled Water	10 c.c.'s	Iodine	0·1 ,,
		Distilled Water	5 c.c.'s

Prepare A solution first by adding the water to the chloride and allowing the latter to dissolve entirely. Meantime prepare B solution by adding a few drops of water to the iodide and iodine crystals (preferably in a conical flask) and after dissolution add the remaining water. Heat will be necessary to obtain perfectly dissolved solutions. Before proceeding further, the solutions must be covered and left to cool thoroughly, after which B solution is added to A. Allow the mixed liquor to stand for 24 hours to settle the sediment and then decant the clear liquor off into a stoppered dark glass bottle. It is beneficial to add a crystal of iodine before stoppering the bottle. This solution will not indefinitely maintain its efficiency, hence it is necessary to renew it from time to time.

The colour reactions of this solution on different types of fibre are—

Light to Dark Claret.	*Blue to Claret.*	*Blue to Red Violet.*	*Violet Blue to Blue.*	*Blue.*	*Olive Green.*	*Yellow to Colourless.*
Linen Cotton Hemp	Esparto (Both colours often appear on one fibre	Adansonia	Straw	Chemical Wood Pulp	Manilla	Brown Mechanical Mechanical Wood Pulp Unbleached Jute „ Straw

The method of application is the same as for the other solutions.

A further formula for colour reaction is to use the Herzberg solution as outlined, and, after allowing about one minute in which to react, remove the excess and treat the stained fibre with one drop of sulphuric acid which has been diluted in solution with four-fifths bulk of distilled water. The colours now appear its according to the table—

Violet to Wine Red.	*Blue to Blue Grey.*	*Gold Yellow to Dark Yellow.*
Cotton Linen Bleached Jute	Chemical Wood Straw	Mechanical Wood Pulp Unbleached Jute Impure Fibres

Apart from these solutions, which are for microscope work alone, there is a series of colouring reagents mainly used in testing for the presence of mechanical wood-pulp. With one exception, these test solutions produce their colorations in broad areas on the finished sheet, hence no microscope is requisite for their observance. Chemical wood-pulp, which differs from mechanical wood-pulp in that it has had the ligneous and other impurity removed, does not react with the solutions about to be described.

Phloroglucinol Solution.

Phloroglucinol	2 grammes	or	4 grammes
Absolute Alcohol	25 c.c.'s.		100 c.c.'s.
Concentrated Hydrochloric Acid	5 c.c.'s.		50 c.c.'s.

The phloroglucinol is dissolved in the acid and, after standing, the alcohol is added. If a drop of the solution is applied to paper containing M.W.P., a rosy red stain is produced, varying in intensity according to the percentage of M.W.P. in the paper. As low a proportion as 0·1 per cent may readily be detected.

For testing red papers, the following solution could substitute phloroglucinol.

Benzidine Hydrochloride. Treat 15 grains of chemically pure benzidine with fifteen drops of pure condensed hydrochloric acid. Dissolve the product in 2½ drachms water at 122° F. On application to a paper containing mechanical wood-pulp, an orange coloration will result.

Aniline Sulphate. This serves the same purpose as the preceding solution, and is prepared by dissolving 1 gramme of the sulphate in 50 c.c.'s of water, and acidifying with two or three drops of sulphuric acid. The water will require bringing to boiling point in order to dissolve the aniline sulphate. Applied in the cold to paper containing M.W.P., a vivid yellow stain is produced. It is important to observe that a 1 per cent solution of aniline sulphate will produce a pale pink coloration on paper containing straw or esparto, on boiling in a test-tube.

Alpha Napthylamine Hydrochloride. This is an equally valuable reagent for the detection of M.W.P., and is prepared by boiling a little of the named compound in water to which a drop or two of hydrochloric acid has been added. With this solution, a bright

orange stain is produced if M.W.P. is present in the paper. Additional reagents are Dimethylparaphenylenediamine (Wursters Di-paper) and Ferric Ferricyanide the former creating a deep red stain and the latter reacting with lignine to produce Prussian blue.

CHAPTER IV

TREATMENT OF MATERIALS

RAGS—ESPARTO—STRAW

THE production of paper from raw material comprises, mainly, four stages, namely, the preparation of what is technically termed half-stuff, the conversion of half-stuff into pulp, the construction of the sheet or web of paper from the pulp, and, finally, the finishing of the paper.

Tracing the conversion of raw material into half-stuff, it is preferable first to consider the treatment of rags, which are held to constitute the ideal material for high grade manufacture. The rags used are derived from home and foreign sources, sorted according to class of material or fibre, condition and colour. In the case of the best papers, the rags usually undergo a further sorting in the mill. Trade designations vary according to the origin of the rags, and consist of such terms as extra, white and grey linens, white and coloured cottons, superfines, outshots, seconds, clean, and seconds canvas, jute bagging, etc.

On arrival at the mill, the rags contain an amount of impurity, including loose and fixed dirt, buttons, rubber, colour, glue, dye, wax, resin, starch, and size, which necessitates a mechanical and a chemical cleaning.

The first step towards the preparation of rag-stuff, consists in cutting up the rags into small pieces. In the case of high-grade papers, the cutting is performed by women, the rags being drawn across a knife blade fixed at an angle, and sorted out in receptacles according to colour and material. In the process, an amount of

dirt and dust is loosened, falling through a wire mesh sieve. Quite the majority of mills perform their rag-cutting by machinery. Hand-cutting is no doubt superior, inasmuch as it permits a more careful sorting and removal of buttons, etc. The cutting machine is, however, much more speedy and is thoroughly efficient on all ordinary grades of stuff. The rag-cutter consists of a revolving wheel fitted with knives and a fixed knife, against which the former performs the cutting. The material is fed into the machine on a travelling apron, and the chopped rags are ejected into a trough beneath. Nuttall's rag-cutter is the principal machine in use, and by an improved mechanism is enabled to cut 20 to 30 cwt. of rags (according to size of machine) both ways into small square pieces per hour. The cutting on this machine is performed by two guillotine knives or a guillotine blade and a revolving knife.

In some mills the cut rags are carried on a travelling belt, against which girls are positioned to pick out the various types of conspicuous impurity. The rags are then passed to the willow and duster, which may consist of combined or separate machines. The purpose of the procedure herein is the elimination of dust and dirt, and the partial rending of the fabric. The willow consists of two revolving drums, fitted with teeth which act against fixed teeth in such a manner as to achieve the purpose mentioned. From the willow the rags continue their journey to the duster, which comprises a hollow case enclosing a revolving drum, the dimensions of which are 7 or 8 ft. by 3 ft. The drum is lined with ¼ in. mesh wire and is fitted with teeth projecting inwards. In motion, the drum revolves and vigorously dusts the rags, the dust falling through the sieve into a catcher. The approximate capacity of this machine is 3 cwt. of rags per hour.

After chopping and dusting the rags are ready for boiling, but it is the custom in the production of highest grade rag-stock to wash the rags first, as a means of removing surplus dirt. The purpose of the boiling is to remove chemical impurity and attached foreign matter from the rags, at the same time imparting a certain softness to the material. The agent employed for boiling consists of an alkaline lye, capable of converting the chemical and other impurity into removable soaps. Caustic soda is most generally used, though, in the case of jute and low grade rag-stock, lime may be employed. In some mills a mixture of lime and soda is used, though, chemically, this amounts to the equivalent of caustic soda, as the reaction results in the production of caustic soda and the liberation of calcium carbonate, the latter playing no part in the cleansing of the material. A principal point of difference between boiling with lime or soda is that the former converts the dirt into insoluble soaps while the latter creates soluble soaps, which are much more easily removed in the subsequent washing process. Caustic soda is a dangerous reagent if employed in excess (an accident which seldom happens in practice), whereas caustic lime is harmless, due to the fact that its solubility in hot or cold water is chemically limited. (Lime dissolves in 700 parts of cold water, whereas of boiling water 1,500 parts are required.) Lime, however, does not efficiently remove impurity, and is, therefore, not to be compared with caustic soda so far as the production of high grade white paper is concerned.

The boiling process is performed in large kiers of special design according to the class of material to be treated, and is conducted under specified conditions as to temperature, pressure, and strength of liquor. The period of boiling varies considerably, and depends

upon the nature of the rags and the character or quality of paper to be produced. For a good quality of paper, the boiling data would approximate to the following—

Period of Boiling	5 hours upwards
Steam Pressure	25 lbs.
Na OH. (Caustic Soda)	5% on weight of rags

For boiling with lime, the following data represents average practice—

Period of Boiling	10 hours
Steam Pressure	45 lbs.
Lime	10% on weight of rags

The type of kier or boiler employed for the boiling of rags may be either spherical, revolving or stationary vomiting, the former on low-grade stock and the latter on high-class. At this juncture, the various types of boiler may appropriately be described, in order to avoid repetition during the later discussion of the treatment of other sorts of material.

Of boilers, or kiers, there are two main classes, revolving and stationary, and of the former there are, again, two types, spherical and cylindrical. The modern stationary boiler consists of an upright cylindrical kier, riveted throughout and fitted inside at the top with a sprinkling chamber (for the effective distribution of the liquor) the full diameter of the boiler. To effect the constant circulation of the liquor, conveyance pipes are riveted to the inside of the boiler shell, and, for the drainage of the waste liquor and wash-water, a perforated false bottom is provided.

The spherical revolving boiler comprises a circular kier, built up of riveted plates, and approximating in dimensions 8 or 9 ft. diameter, the same revolving on hollow journals supported on wrought-iron standards. Steam enters through the hollow journal and is, by a

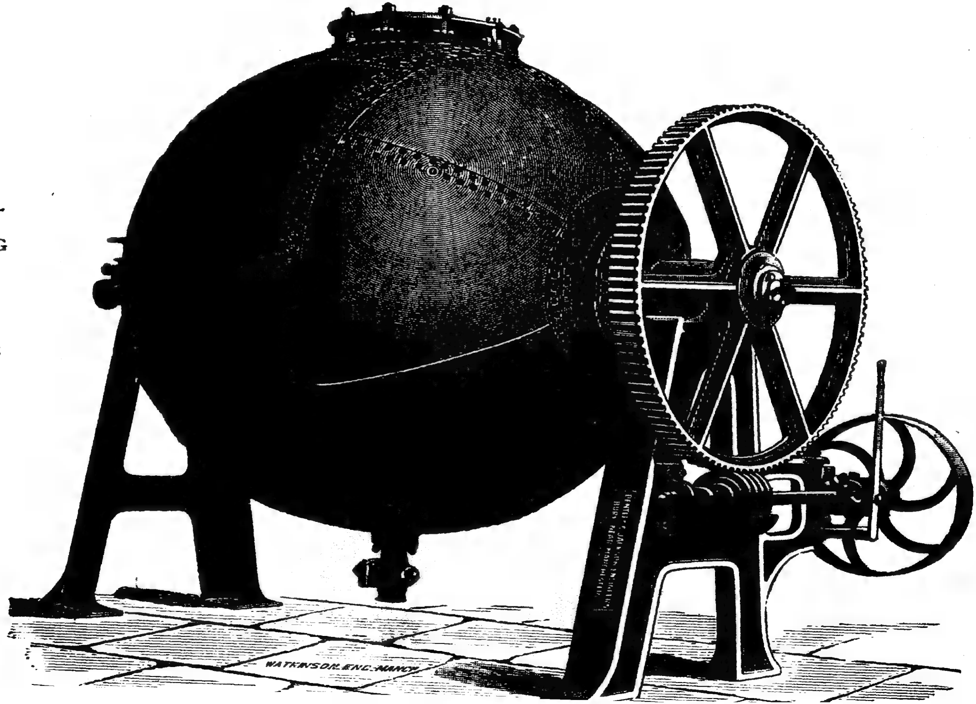

FIG. 10

SPHERICAL

REVOLVING

BOILER

(Bentley & Jackson, Ltd.

suitable device, distributed through the boiler. A false bottom is fitted to the interior in order to preserve a clear exit for the waste lye.

Cylindrical boilers are constructed on the same principleas the foregoing, excepting for the shape, which is signified by the designation. The dimensions of a typical boiler are 18 ft. by 7 ft. The ends are usually convex, and the shell of the cylinder is provided with two large manholes for the purpose of loading and discharging the material. The inside of the boiler is fitted with a steam distributing pipe and a perforated strainer plate the full length of the boiler, for drainage purposes.

During the boiling, the liquor should be tested occasionally to ascertain the progress and condition of material and consumption of alkali. By this method the process may be scientifically controlled and the utmost efficiency secured at minimum cost, both in chemicals and time. Rule of thumb methods obtain in too many mills, often with the result that boiling is uselessly prolonged or excess of soda added.

It is the custom in certain mills making high-class writings to perform a wet-picking after the boiling is complete, the process consisting of the removal of conspicuous refuse by female labour.

The boiling having been completed and a slight water wash applied, the material is thoroughly softened and is in a state of partial cleanliness, but it still holds an amount of chemical or mechanical impurity, to effectively rid which the process of washing requires to be performed. The engine in which the washing is conducted is known as the breaker, or hollander, and consists of a wide oval trough fitted inside with a partition known as the mid-feather. The mid-feather stops short of the ends of the trough, thus providing a

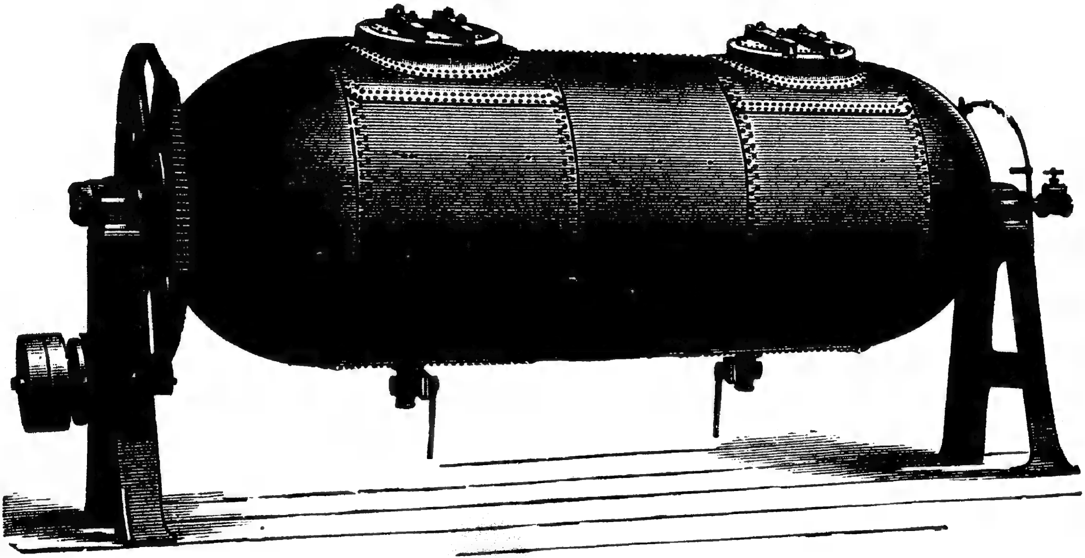

FIG. 11. CYLINDRICAL REVOLVING BOILER
(Bentley & Jackson, Ltd.)

sort of continuous channel. Referring to the illustration, it will be seen that there are two drums, one each side the mid-feather. These are designed to perform the respective operations of rending the rags and removing the dirty water. One drum carries on its surface a series of blunt steel or phosphor bronze knives, which, as the drum revolves, come into more or less close contact with an opposing set of fixed knives fitted on the bed of the trough directly beneath the drum. The drum itself is adjustable and may be raised or lowered, according to the character of breaking desired. The floor of the trough assumes a rise upward to the knife drum, technically termed the breast; immediately following this comes the back-fall, or downward slope. By this means the onward flow, regulation of maceration, and effective circulation of the material is controlled. The drum in the compartment or channel at the opposite side of the mid-feather is termed the drum-washer, and consists of a frame covered with fine wire cloth. Inside the drum is an arrangement for conducting away the dirty water which is continually passing through the wire mesh. Various devices are in use to effect the removal of this dirty water. The principal methods consist of either a syphon pipe or bucket arrangement, the latter being more generally adopted. The syphon device comprises a pipe with a cone or trumpet-shaped end, which passes into the drum washer through the drum shaft. To start the suction action, the syphon requires to be charged first with water, following which the dirty water from the washed rags is continually abstracted. The bucket method depends upon a series of bucket-shaped compartments inside the drum washer, which work on the principle of the dredger and automatically pick up the dirty water as the drum revolves. The buckets are connected with the hollow

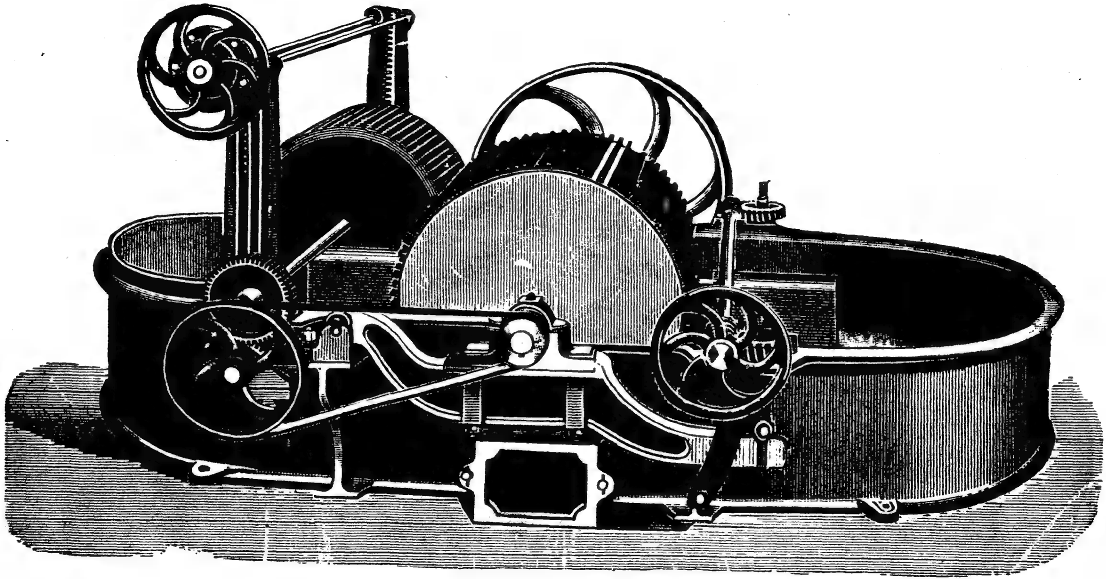

FIG. 12. BREAKING ENGINE (HOLLANDER)
(Bentley & ack on, Ltd.)

shaft on which the drum rotates, and through this medium the dirty water is passed to the drains.

Operations performed in the breaker comprise loading up with water and gradually adding the required amount of boiled material, the drums meanwhile having been set in motion. The height of both the drum washer and knife drum is regulated to suit the condition and character of the material, gradualy being lowered as the action proceeds. In washing and breaking the object is to cleanse, rend apart, and brush out the material, hence the knives do not require to be sufficiently lowered actually to cut the rags. The revolutions of the drums cause the contents of the breaker to circulate round the channel. Meantime the knives gently commence their work, and the shape of the breast and backfall facilitates the travel of the mass. Simultaneously, the drum washer bales out the dirty water, clean water flowing in at an equal rate. Incidentally, the drum removes some fibres, which, in modern practice, are recovered in what is termed a save-all.

When sufficiently cleansed and rended, the material reaches the stage at which it is termed half-stuff, and at this juncture bleaching is usually performed. The method adopted varies, some mills bleaching in the breaker while others prefer the use of potchers or bleaching chests.

Before bleaching, the half-stuff, though clean, is quite discoloured and contains an amount of non-cellulosic matter. The purpose of the bleaching process is to whiten the material and remove the foreign organic matter as completely as possible. The agent in general use is bleaching powder, or chloride of lime. The action of bleaching is essentially one of oxidation. Bleaching powder is a complex salt containing calcium

chloride and calcium hypochlorite. The active portion is represented by the chlorine contained therein, which is technically known as the available chlorine. The total available chlorine in good bleaching powder is 35 per cent. In contact with water, the chlorine unites with the hydrogen and liberates oxygen in a nascent state. This oxygen actually effects the bleaching action, and the proportion liberated depends upon the amount of chlorine contained in the bleaching powder. The colouring matter and organic impurity contained in the half-stuff is composed of carbon, hydrogen, and oxygen. If the hydrogen is removed, the colour or impurity becomes destroyed. What actually happens in bleaching is that the oxygen liberated by the chlorine constituent combines with the hydrogen aforementioned and thus decomposes the colour impurity.

The bleach solution is prepared by dissolving the bleaching powder in water in a cast-iron tank, fitted with revolving stirrers, which keep the contents of the tank in constant agitation. After a sufficient time (about two hours) the sediment is allowed to settle for half a day, following which the clear liquor is run off. The residue or sludge is tested for traces of bleach and, if economical, a further quantity of water is added for the purpose of extracting all the available bleach.

Liquid chlorine is now available and is used in some mills along with lime to the exclusion of bleaching powder.

The bleach solution is next added to the half-stuff in the breaker, potcher, or chambers, according to the mill method. In the case of bleaching chambers, which are not much used, the material is heaped up and warm bleach circulated through the mass. The chamber is lead-lined and provided with a perforated false bottom for drainage. The average amount of

bleaching powder used to whiten clean rags is 3 per cent on the weight of the rags. In the case of low grade rags, at least 5 per cent of bleach is necessary.

To accelerate the bleaching action, heat is often resorted to, but unless carefully controlled the method is dangerous and liable to injure the material (especially esparto) if the temperature exceeds 90° F. The probability is that oxy-cellulose will be formed, with the inevitable tendering and lowering of colour in the ultimate product. Again, dilute mineral acids are sometimes added during the bleaching process, with the purpose of forcing the bleach to speedily yield its available chlorine. The method has its drawbacks, and great care is essential to avoid leaving traces of acid in the pulp. To secure the utmost efficiency in the bleaching process, the most generally approved plan is to use a fairly strong bleach solution and maintain a constant agitation, the half-stuff being uniformly warm throughout the mass.

Various methods of manufacturing bleaching solutions by the decomposition of certain chemical bodies in contact with electric current have been suggested, including the Hermite, Kellner, and Andrioli processes. Among the advantages claimed for electrolytic bleach are economy of chlorine, preservation of fibre strength, quicker and more even bleach, cleanliness of preparation, and closer control over efficiency. One of the successful systems is the electrolyser associated with the names of Haas and Dr. Oettel. The principle on which this electrolyser is based is that of the dissociation of common brine and conversion into sodium hypochlorite. The apparatus consists of a stoneware tank fitted with a system of cells and electrodes of graphite composition. Above the electrolyser is situated a brine-mixing vat. In practice, the tank is loaded with water and a measured quantity of salt, which is then mixed for five minutes

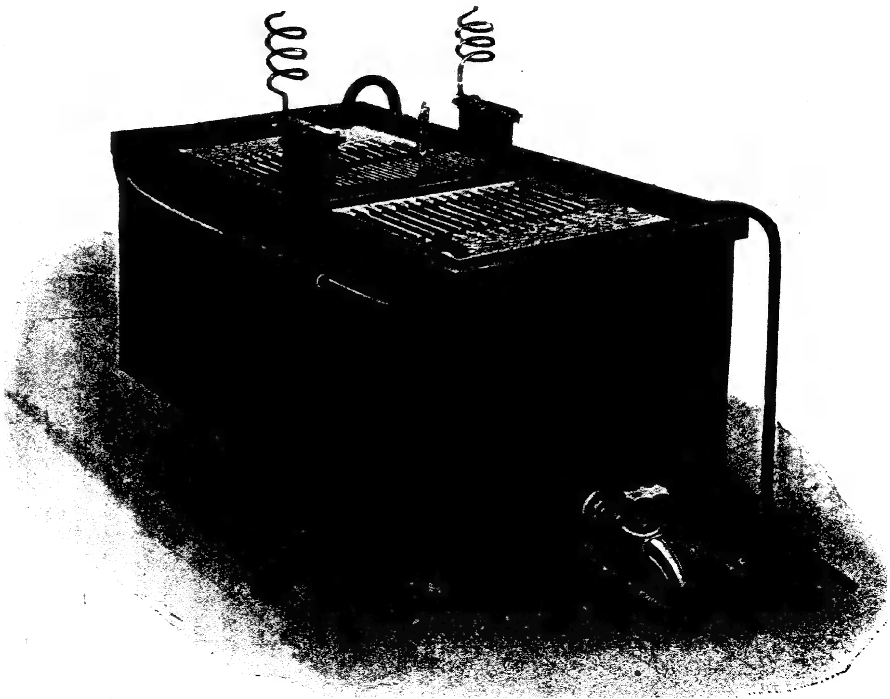

Fig 13

HAAS & OETTEL

ELECTROLYSER

and allowed to stand for an hour or two. The brine is run off into the electrolyser and the current switched on. The action of the current causes the salt to split up into sodium and chlorine, the former splitting up the water and releasing hydrogen which, being lighter than the liquor, travels upwards, and by the pressure thus exerted forces the solution to circulate through the cells and through a series of cooling pipes. When the liquor reaches the desired strength of active chlorine it is run off into a tank beneath the electrolyser, from which it is withdrawn for immediate use.

With the advent of liquid chlorine as a commercial proposition mills are now turning their attention to the advantages of re-chlorination of lime residue or carrier lime in bleaching powder.

The material, or half-stuff, having been thoroughly bleached and partly reduced to pulp, requires still further treatment to render it sufficiently fine for the purpose of forming an even-textured and closely-woven sheet, capable of withstanding pen writing, printing, etc., according to the class of paper being made. The processes involved in this further treatment are described in Chapter VI.

From the sorting of the rags up to and including breaking and bleaching processes, the average loss on the treated material amounts to something like 12 per cent. In other words, for every 100 lb. of rags, 88 lb. of half-stuff is produced.

Treatment of Esparto. Esparto grass is subjected to a treatment similar in principle to that described for rags, but modified to suit the peculiar requirements of the material. The grass itself is imported into England from Spain and North Africa, and arrives at the mill in the shape of large bales of wiry grass bound round with hoops or esparto rope. The raw material contains

a large amount of dirt and silicious matter, the latter being present in the loose state and also bound up with the stems through incorporation during growth. The plant itself contains a large proportion of matter valueless to the paper-maker, the quantity and character varying according to the origin of the esparto. Spanish grass is held in the highest esteem, and in the case of this grade about 50 per cent of non-cellulosic matter requires to be eliminated during the preliminary processes of paper-manufacture. The African grades yield, approximately, 45 per cent of cellulose.

On arrival at the mill, the first process consists in removing the esparto binding ropes and loosening the grass, the latter being fed into a dusting machine or willow. This machine, or engine, as paper-makers term their details of plant, consists mainly of an horizontal conical drum revolving in a removable sheet-iron cover. Both drum and cover are fitted with rows of spikes, which break and rend the grass apart, loosening it so that the stones, sand, dust, etc., fall away and are sucked by draught through a wire sieve.

In some mills the dusted grass is delivered by a hopper on to a wide belt, travelling upwards at an angle of 25°. At periodic distances alongside the belt, stages are improvised on which females are stationed for the purpose of picking out visible impurities which have escaped the willow.

The more modern practice, however, is to omit this operation in favour of the presse pâte system, presently to be described. By this omission, a saving in labour and time is claimed, without detriment to ultimate quality. From the willow, the grass is conveyed to the boilers direct. The boiler most generally employed is an upright stationary cylinder of the "Sinclair" vomiting type, and the agent used is caustic soda.

The charging of the boiler is accomplished by gradually adding the grass, steaming it, and adding the caustic lye as the operation proceeds. In this manner, the grass is softened and the bulk considerably reduced. A normal charge comprises from 2½ to 3 tons of grass, and the average data for the boiling is 18 lb. of 60 per cent caustic soda per cwt. of esparto; 35 lb. pressure per sq. inch ; period of boiling, 2½ to 3 hours.

When the boiling is complete, the spent lye is run off into a tank and retained for the purpose of recovering the soda. Soda recovery is an important factor in the process of paper-manufacture from grasses. The operations connected therewith are described in Chapter V. Meantime, the boiled grass is transferred to the breaking engines or hollanders, where it undergoes a washing and breaking treatment similar to that described under the heading of rags.

Some mills prefer to wash the grass by the lixiviation process, which comprises a series of tanks loaded up with grass, and through which a stream of water travels. Pure water enters the first tank, and during its traverse becomes strongly charged with foreign soluble matter and lye, ensuring a minimum volume of water, speedy evaporation, and economical soda recovery.

The bleaching of the half-stuff is effected by various methods, but in each case bleaching powder is the agent employed, the amount required averaging 8 per cent on the weight of the grass, and the period of bleaching extending from 2½ hours upwards. The general method is to bleach in the breaker or potcher as with rag half-stuff. A less popular system depends upon the employment of large chambers, in which the half-stuff is maintained in a state of constant agitation by revolving paddles. Another method in practical

use is the "Tower" system of bleaching introduced to this country by Masson, Scott & Co., Ltd. The "Tower" system comprises a series of vertical cylindrical vessels, each about 16 ft. by 8 ft. 6 in., through which the half-stuff is pumped, coming in constant contact with the circulating bleach liquor. This principle is held to secure the maximum efficiency of bleaching in an economical manner. The action proceeds as follows: the half-stuff is raised from the potcher to the first tower by a patent circulator. The tower is fitted with a concentrator by means of which the water is removed from the half-stuff in order to permit the free action of the bleach liquor, which is added at this stage. The half-stuff is now delivered to the next tower, leaving the first tower free for a fresh charge. The contents of No. 2 are afterwards transferred to No. 3, and No. 1 to No. 2, and so on until all the towers are at work. The special advantages of the system are that water is removed before the bleach is added, and the spent liquor is removed on completion of the process by means of a concentrator fitted in the last tower of the series. Each time the half-stuff is transferred from one tower to the next it is thoroughly mixed by the circulators, thus securing uniformity of colour and quality.

On completion of the bleaching process, the esparto half-stuff is drained and transferred to the stuff chests attached to the presse pâte. This machine is very similar to the wet-end of the paper-making machine, and comprises stuff chests, sand-table, coarse strainers or screens, mixers, travelling wire, suction rolls and boxes, couchroll and reeler. The half-stuff is converted into a cohesive web, closely resembling thick wet paper or cardboard. The purpose of this intermediate process is to eliminate all coarse dirt and impurity,

and prepare the material thoroughly for the subsequent beating process.

Treatment of Straw. Several varieties of straw are employed in the process of paper-making, mainly on the Continent, where it takes the place that esparto occupies in Great Britain. Wheat and rye yield the most suitable fibre, oat straw giving a hard and tough, but long, fibre, while the barley fibre is short and lacks the necessary strength. Oat straw is largely used in mixture with wheat, the one helping to tone down the other.

The treatment of straw is similar, but much more drastic than that of esparto, owing to the greater proportion of combined impurity and the extreme hardness of the raw material. The presence of knots or nodes on the stems constitutes a peculiar difficulty with straw and creates trouble in the bleaching process. An average yield of cellulose from straw, under mill conditions, approaches 40 per cent, although the theoretical content reaches 50 per cent and over, according to the type of straw.

The first step in the reduction of straw is the chopping process, performed in a chaff-cutter. Here, the material is cut to short pieces, following which an air blast carries it to a box sieve encased in a large chamber, where the dust and loose foreign matter is separated by the draught and falls through the sieve. The clean straw is then baled and conveyed to the boilers, the charging process being conducted in a similar manner to that described under esparto. Caustic soda is employed as the boiling agent, the proportion averaging about 6 to 8 cwt. per 40 cwt. charge. The boiling may be performed in either rotary cylindrical boilers or kiers of the stationary vomiting type. The chief objection to rotary boilers is that the material is apt to mass in

the centre, thus preventing efficient circulation of the lye. The period of boiling extends over six hours, at a temperature of 300° F. and 60 lb. steam pressure per sq. inch. On completion of the boiling, the straw is sufficiently reduced to flow through a pipe into a large chest, where the excess liquor is drained away. To further eliminate impurity and residual lye, the material is washed and broken into half-stuff in the potcher or hollander. The treatment here and the subsequent bleaching resembles that of esparto, about 4 per cent of dry 35 per cent bleaching powder being consumed. At this stage the half-stuff is run over the presse pâte.

Bamboo has in recent years come into prominence as a suitable raw material for paper-making, mainly as a result of the investigations of Messrs. Raitt, Pearson, & Sindall, carried out on behalf of the Indian Government. Of bamboo trees, there are hundreds of species, of which it has been found that only about five are suitable for pulp. These five species, however, represent approximately 80 per cent of the total wood grown. The tree abounds in India, Japan, the Indies, and hot climates generally, growing to a height of 30 ft., and becoming established in three years. For paper-making purposes, it has the advantages of prolific growth, easy collection and transport, and cheap native labour. Paper can be made from bamboo fibre equal to that produced from wood or esparto, especially in the direction of book and magazine stock. The chief difficulties hitherto encountered in the treatment of bamboo have been occasioned by the nodes, the buoyancy of the material in the digesters, resistance to penetration by the liquor, and the obstacles toward the production of a good white by bleaching. Recent investigations (by Wm. Raitt, of the Forest Research Institute, India) have removed much of this difficulty, and it is now possible to produce

a good white pulp by economical treatment. Briefly outlined, the following represents the approved procedure for the production of pulp from bamboo. The wood is chosen according to species, following which the stems are cut and the branches removed. Formerly, the nodes (or joints) were cut away (representing a waste of 7 to 15 per cent) but in modern practice this operation is unnecessary. The stems are crushed and chipped to fine fragments, in which state they are given a preliminary boiling in hot water to remove much of the starchy substance that would otherwise interfere with the bleaching. The chips are then digested with 16 to 20 per cent of caustic soda, or, alternatively, with a mixture of three parts caustic and one part sulphide, for five to six hours under a pressure of 24 lb. upwards. Following the draining, washing, etc., the pulp is bleached with 18 per cent of bleaching powder, calculated on the air-dry pulp. In the case of the soda and sulphide boiling, still less B.P. is required. The yield of unbleached fibre approximates to 45 per cent. on the dried and seasoned bamboo, and of bleached fibre, 40 to 43 per cent.

Bagasse, or **Megasse,** is the woody fibre left after extracting the juices from the sugar cane. The process of treatment for the production of paper is similar to that followed in the case of bamboo. The stems are dried, separated according to quality and character, and afterwards crushed and splintered ready for boiling. Various systems have been patented for the preparatory treatment of the stems and for the removal of foreign impurity. The resultant fibre is low grade and cannot compare with that of bamboo. Being short and soft, its probable application will chiefly consist in blending with other and longer fibres.

Among other types of raw material recognized as

available for the manufacture of paper may be mentioned "brokes" and waste printed paper, jute, and rope; while more recent sources of papermaking material embody native grasses of many kinds, papyrus, etc.

"Brokes" is the name given to the waterleaf or paper which is spoiled during the course of manufacture at the machine, either by sticking at the couch rolls or presses, breaking across the web, or running out extra thick or thin, etc. Commonly, this material is put back into the beating engine for re-conversion to pulp, unless it has passed the drying cylinders, in which case it is gathered for a weak re-boiling and disintegration. Primarily, the fibres so produced are used as a sort of filler, owing to the fact that the repeated treatment results in a shortened fibre. Apart from ordinary mill brokes, a large business is carried on in waste or used paper, which is collected, sorted according to quality and colour, and sold to paper-makers for re-conversion into clean and continuous paper. The methods employed and suggested for the reduction of the material vary considerably according to the requirements and plant of the mill. If the waste is to be re-pulped and shortened in fibre to act as a filler, the older practice is to mill it out under the action of an edgerunner or kollergang. This engine consists of a pair of circular grindstones with grooved periphery, which revolve on a granite bedstone in a trough in which the material is held in water. The rubbing or teasing out action results in a more or less thorough disintegration of the paper and the production of a pulpy mass. In recent years the kollergang has largely given way to the superior capacity and efficiency of pulping engines, of which there are several types in use, including Cornett's Patent Cone Breaker, the Perfect Pulper (Masson, Scott & Co., Ltd.), Walmsley's Conical Willow, and

Lannoye-Thiry's Pulper. In these engines a charge of waste is reduced to pulp ready for the beaters in a short space of time and without injury to the fibre. Though differing in detail, the principle of action is closely similar with each type of pulper. Essentially, the machine consists of an outer case, cone-shaped, fitted inside with teeth or pegs, and an internal cone or shaft,

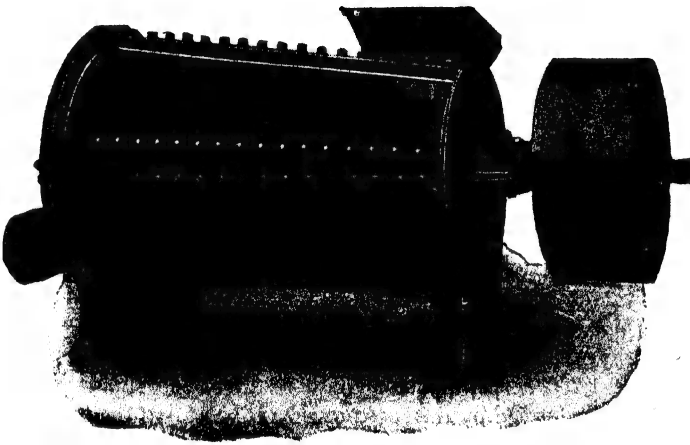

FIG. 14. CORNETT'S PATENT CONE BREAKER
(J. Bertram & Son, Ltd.)

fitted with complementary sets of projecting teeth or arms. The waste paper is fed into a hopper at the narrow end of the cone, and steam or water is applied to the charge. The material becomes soaked and softened by the liquor, and, as the internal cone rotates, it is rubbed and squeezed apart. No cutting takes place, therefore the fibres are preserved intact. On reaching the wide end of the cone, the disintegrated material is ejected through a pipe into the service-box or direct to the beaters.

The foregoing process is suitable only for clean brokes and waste. Various systems have been suggested and tried for the utilisation of soiled and printed waste, but with little success, except in the manufacture of common browns, etc. A recent American system for waste paper treatment comprises two concentric cylindrical tanks, the inner one being fitted with a draft pipe which discharges its contents at a tangent into the outer tank. In use, the waste is fed into the inner tank along with a charge of water, steam being intermittently applied. After a preliminary treatment, the soaked material is drawn down to the draft pipe, the latter carrying in its interior, lengthways, a shaft on which two propellers are spaced and set at a different pitch. In action, these propellers rotate at a speed of about 2,000 revolutions per minute, thus exerting a sufficient force to draw the material downwards into the pipe. On completing the traverse through the pipe, the broken material is delivered at a tangent into the outer cylinder, the speed of delivery being estimated at 1,200 ft. per minute. As a result of the opposing forces formed by the speed of the propellers on the one hand and the inertia of the material and liquor on the other, a de-fibreing or disintegrating effect is carried out on the material. This process is aided by the creation of a partial vacuum, due to the different pitch of the propellers, which exerts a pulling and rending action on the paper, tending to cause disintegration. The cycle of operations proceeds continuously until the desired separation of the fibres has been attained, the material passing from the inner tank to the propellers, thence being forced spirally upwards into the outer tank to cascade over the top into the inner tank ready for repetition of the process.

Simultaneously with the de-fibreing, a cleansing, or

de-inking, operation is effected. For this purpose, a soap or alkaline solution is added to the liquor in the cylinder. The agitation induced by the action of the propellers promotes and intensifies the effect of this solution, causing it to dissolve or loosen the colouring matter, which may afterwards be readily removed by the ordinary washing process.

The following results are claimed by the promoters of this system—

500	lbs. of	Ledger waste,	completely	de-fibred and	cleansed in	30	min.
500	,,	Book	,,	,,	,,	25	,,
500	,,	News print	,,	,,	,,	20	,,

CHAPTER V

MANUFACTURE OF WOOD-PULP—SODA RECOVERY

Wood may now be regarded as the premier paper-making raw material of the world. In England, it is commonly employed in the manufacture of all grades of paper, from common newsprint to bonds and account book papers. It is not common practice in the United Kingdom to produce the actual wood-pulp, timber and water supplies being inadequate for the purpose. Wood-pulp is, therefore, produced in those countries possessing immense tracts of forest, and is exported in the form of sheets or boards of what is technically known as half-stuff. The chief pulp-producing countries are Canada, U.S.A., Scandinavia, Germany, and Russia. To produce 1 ton of common newsprint paper requires a pile of logs measuring about 4 ft. square by 11 ft. high, and for 1 ton of dry mechanical wood-pulp eight to ten trees are used up, therefore it will readily be seen that the cost of conveyance constitutes an economic difficulty in the way of home manufactured wood-pulp. To be commercially successful, it is essential that the pulp-mills be situated close to the timber tracts, or linked up by cheap water transit which will allow of the logs or rafts being floated down stream to their destination.

The trees principally employed in the production of wood-pulp belong to two groups, the coniferous or cone-bearing tribe and the deciduous (*dicotyledonous*) or leafy series. The principal representatives of the former include spruce, pine, balsam fir ; and of the latter, poplar, aspen, birch, and beech, the last two being only rarely employed. The trees of the coniferous group

yield a longer and tougher fibred pulp, those of the deciduous group yielding a short-fibred pulp more after the nature of straw or esparto.

Of wood-pulp, there are two main types, mechanical and chemical, the designation implying the mode of conversion from timber to fibred pulp. Mechanical wood-pulp is produced by merely grinding the logs in contact with water, thus retaining in the ultimate paper practically all the impurity of the wood. Chemical wood-pulp, on the other hand, is produced by boiling the chips with various alkaline or acid reagents, thus extracting the bulk of the original impurity. According to the type of boiling agent employed, the product receives its trade nomenclature. Soda-wood is prepared by boiling under the influence of caustic soda; sulphite wood by digesting with the bisulphites of alkaline earth metals, as calcium or magnesium; sulphate wood by boiling with sodium sulphate (in practice, reduced to sulphide). The character of the resultant product differs essentially, according to the type of treatment. Mechanical wood-pulp partakes of the nature of the raw wood and is brittle, discoloured, and impure. Soda wood-pulp in some degree resembles the pulp from esparto and cotton, being soft, bulky, and fairly pure. Sulphite is harder, more transparent, resembling linen; while sulphate is mainly preferred for its tenacity and strength. Mechanical is used in the manufacture of news and common printings; soda wood-pulp in the manufacture of magazine, book printings, cover papers, and writings; sulphite, as an admixture in news and printings, but more largely in cap papers and wrappings; sulphate is unsurpassed in the production of the well-known kraft brown papers.

It has been computed that of the available cellulose in wood (which averages 55 per cent), the sulphite

process yields 80 to 85 per cent; sulphate, 65 to 70 per cent; and soda, 60 to 65 per cent.

Mechanical wood-pulp was first experimented with by Schoeffer in 1800, and again by Koops in 1851, but for its practical introduction we are mainly indebted to Keller and Voelter in the year 1840. The process for producing soda wood-pulp was first suggested by Watt and Burgess in 1853; Blitz (1853), Jullion (1855), and Dahl (1884) share credit for the introduction and development of sulphate boiling and its modifications; while Tilghmann first discovered the possibilities of boiling with sulphurous acid and bisulphites (1866), but left it to Mitscherlich (1874) to become world famous as the father of the sulphite process proper.

Manufacture of Mechanical Wood-pulp. Spruce, balsam fir, poplar, and aspen are the principal species of timber employed in the manufacture of mechanical wood-pulp. The first stage in the process of pulp production consists in felling the trees and the removal of useless branches, etc. The trunks, or logs, are then conveyed by special rail wagons or by making up into rafts and floating down stream to the pulp-mill. On arrival at the mill, the logs are grappled, hauled in, and by special conveying devices carried forward to the circular-saw machines, which cut the logs down to 2 ft. lengths. The bark is next removed from the logs, either by hand or machine, the former method being more rarely employed owing to the cost and length of time required. In the hand-barking process, the bark is cut away with an implement which closely resembles the common spokeshave. The barking machine consists of a rapidly revolving disc, from which three knife blades protrude at a fixed angle, after the manner of a joiner's plane. The logs travel underneath the knives, and the bark is skimmed off to leave the timber clean.

During the barking process, the wood loses from 10 to 20 per cent in weight. To accommodate the width of the grinding stone, it is necessary to split the logs to a convenient thickness, following which the knots are removed as completely as possible, and the wood passed forward to the grinding machines. The grinding machine consists of an emery or sandstone cylinder, about 4 ft. diameter by 15 to 30 in. width of face, the face being grooved and serrated to exercise the maximum de-fibreing effect upon the wood. According to the type of grinder employed, the logs may be either held in pockets situated at intervals round the surface of the stone, or pressed in contact with the stone under the influence of a heavy platen. In each case, hydraulic pressure is applied to maintain the logs in constant and regular contact with the periphery of the grindstone. To prevent friction burning, and the production of a brittle fibrous yield, also to carry away the ground material in the form of pulp, a constant flow of water is maintained on the stone at periods in close proximity to the timber.

According to the volume of water employed, the resultant pulp is known as hot or cold ground. Hot ground mechanical is produced with a minimum quantity of water and correspondingly heavy pressure, the friction thus created engendering a certain amount of heat. Cold ground mechanical involves the supply of a copious amount of water and a correspondingly lighter pressure. Hot grinding results in the production of a fairly long-fibred and drier pulp than cold grinding, the latter yielding a more wet or greasy pulp, due to the hydrating influence of a longer period of grinding under light pressure and copious volume of water. The method of grinding thus induces a typical character into the ultimate pulp, that of hot ground being more suitable

for fast running news machines, owing to its free nature, while cold ground, by reason of its greater strength and cohesion, is best fitted for printings and book papers made on slower running machines.

Whatever method may be employed, the product of the grinding process is represented by a coarse and irregular semi-pulp, containing impurity and large fragments of wood. To render it capable of forming a regular and cohesive web of paper, further refining or sorting is essential, to effect which the ground mass is run through a centrifugal screen or a series of vibrating sieves varying in the width of mesh. By this means the pulp is separated according to the character of the fibrous fragments. American practice largely depends on the use of coarse vibrating strainer plates to achieve the same end. By each method the larger fragments of wood are retained for further disintegration, while the more minute particles pass forward through the screens. To reduce the pulp to uniform consistency, the coarser material is fed into an engine called the refiner, where it is charged with water and ground down to the requisite condition.

The refining engine (which must not be confused with the machine bearing a similar name, and which is in England employed as an auxiliary or substitute for the beating engine) consists of a pair of circular sandstones, horizontally disposed, the upper stone revolving in close contact against the lower stone, which is stationary. To charge the engine, the pulp is fed in through an aperture in the upper stone, whence it travels to position between the grinders. After being subjected to the process of squeezing and rubbing, the masticated pulp oozes out round the edges of the stones in a somewhat refined condition, and is collected in the trough beneath. It is now ready to be converted into the

half-stuff board or sheet, ready for sale or export. It is to be understood that even in this form the pulp, or, more correctly, half stuff, as imported into Great Britain, requires a further treatment in English mills for the purpose of converting it into a usable paper.

To convert the raw pulp into boards for export, it is run into a vat which contains a revolving wire-covered cylinder. As the cylinder revolves, the wire-cloth picks up on its surface a film of fibre, which is then transferred to a travelling felt. The endless felt carries the wet sheet forward to a pair of rolls, the upper one of which reels the web until a sufficient thickness to form a board is obtained, at which juncture the shell is slit and removed from the roll. The wet sheets of wood-pulp are piled up with interspersed felts, and afterwards subjected to hydraulic pressure to remove surplus moisture, following which they are baled ready for shipment.

According to whether the wood-pulp is completed in the wet or dried state, it is known in the trade as wet mechanical or dry mechanical, the former containing 50 per cent of moisture, and the latter (air dry) 7 per cent.

Before shipping, it is customary to disfigure the wood-pulp bales by piercing, for the purpose of customs identification and assessment, wood-pulp being subject to a lower rate than manufactured paper or board.

Mechanical wood-pulp is a constituent of newspaper (usual proportions, 75 per cent mechanical, 25 per cent sulphite), common printings, handbill papers, and cheap wrappings. Owing to the presence of practically all the original impurity of the raw wood, including lignine, resins, gums, and sap, paper containing M.W.P. in any appreciable proportion speedily loses its nature, becoming discoloured and brittle, due to atmospheric

oxidation of the organic constituents. In the case of coloured posters, etc., the influence on the pigments is most marked, the impurity in the paper chemically reacting to adversely affect the colour, which, in some instances, would otherwise survive the influence of light and air for a sufficiently long period. The tests to determine and roughly assess the percentage content of mechanical wood-pulp in paper were briefly outlined in Chapter III.

Brown Mechanical Pulp. This type of wood-pulp, which stands as a sort of midway product between mechanical and chemical wood-pulp, was first prepared in 1868 by Beyreust (secretary to Prince Bismarck). In practice, the wood is steamed and scalded so as to partly convert the lignous element into a soluble product. The resultant softening enables a longer and more separated state of fibre to be obtained, thus aiding the production of a stronger and more durable type of paper. Most of the original impurity is, however, carried forward into the pulp, and the utility of the material is mainly in the production of wrappings and brown papers.

Soda Wood-pulp. In the manufacture of soda wood-pulp, or soda cellulose, as the bleached pulp from this process is generally known, the types of tree mainly resorted to are those of the soft wood variety, such as poplar, aspen, basswood, etc. The preliminary stages in the conversion of the timber to chemical wood-pulp resemble those described in the production of mechanical wood-pulp, except that, instead of merely reducing the timber to short lengths, the cutting is carried further, the aim being to produce small chips suitable for digesting with liquor. From this point, the routine for chemically boiled pulp differs very materially from the crude grinding of the mechanical process.

The reduction of the cut lengths to a state of chippings measuring in length $\frac{3}{8}$ in. to $\frac{3}{4}$ in. is performed by a machine fitted with a cast steel disc from which knives project. Thus the wood is more easily and thoroughly penetrated by the boiling liquor. Before charging the digesters, the chipped wood is fed into a large revolving screen, with the object of removing much of the dust and dirt which is always present. On completion of this operation, which is known as screening, the clean chips are conveyed to large iron digesters, measuring about 7 ft. diameter by 30 ft. deep, into which they are charged through the manhole, along with caustic soda of 8 per cent strength. The cover is then battened down and steam introduced to attain a pressure of upwards of 100 lb. The boiling, cooking, or digesting (as the process is variously termed), is continued for eight to ten hours, on completion of which the material is discharged from the digester into a receiving tank below. The steam is allowed to escape from the head of the boiler. From the receiving tank, the material is transferred to a large chest fitted with a perforated floor, through which the liquor drains away. To remove strong traces of soda liquor still remaining in the cooked mass, a weak solution is sprayed over the top to percolate through. Any traces which escape the first spraying are eliminated by a further washing with hot water. The whole of these waste, or "black," liquors are conveyed to storage tanks to await the ultimate process of soda recovery, which is one of the essential features in the production of soda wood-pulp as also in the manufacture of paper from esparto (*see* Chapter IV).

After a thorough draining, the partly pulped wood is conveyed from the tanks to the stuff chests, thence to the screeners for the removal of coarse fragments or dirt, and finally to the wet machine, which converts

it into half-stuff board. At this stage the material is of a pale brownish colour, and is known as unbleached soda wood. If required to be bleached, the wet boards are subjected to the action of bleaching powder solution or electrolytic bleach, at a temperature of 60° F., for a period of from four to six hours. They are then passed to the drainers and washed with cold water to eliminate remaining traces of chlorine, which would otherwise react detrimentally to the efficiency of the ultimate paper. After pressing and drying to the required condition of moisture content, the pulp boards are baled ready for export. Throughout the process, from wood to half-stuff, the approximate loss in weight averages over 50 per cent.

Soda Recovery. The waste liquor from the soda boiling contains, in addition to the caustic alkali, an amount of dirt, fibrous matter, and organic impurity from the wood. Owing to the legal restrictions governing the pollution of streams, it is not permissible to discharge the liquor from the mills in this way, therefore other means of disposal have perforce been devised to deal with what is now generally acknowledged to be a source of actual profit. The same ruling applies to the waste soda liquors derived from esparto boiling, as also, but with diminished economy, to the wastes from such other processes as sulphite and sulphate digestion.

Briefly stated, the process of soda recovery, as now practised, consists in first reducing the waste liquor to a syrupy concentrated solution by evaporation, and afterwards incinerating the residue and burning off all organic impurity. The ash which then remains contains sodium carbonate, which, by a further treatment, is converted into sodium hydrate, ready for re-use in the digesting or boiling apparatus. The whole procedure may be considered as consisting of two separate stages,

the first comprising evaporation and incineration; the second embodying the causticization of the product from the first.

The most modern type of evaporating plant is that which works on the principle of multiple effect. By this method, the steam which is generated on heating the liquor in the first effect is further employed to heat and evaporate the more concentrated liquor in the second effect, in conjunction with a diminution of pressure. The lowering of the pressure reduces the boiling point of the liquor, and with each successive effect the same principle is applied, the evaporation of the waste liquor resulting in steam, which is induced to give up its latent heat to boil and concentrate the liquor in co-operation with a controlled lowering of the pressure. Thus the utmost economy is secured, making it possible to recover the soda at an expenditure which allows of a profit being realized in the conversion of waste liquor to usable product.

The principal type of multiple effect evaporator employed in soda wood and esparto mills is the Yaryan, which comprises either three or four effects, according to the amount of waste liquor to be treated. In this apparatus the liquor passes through three or four vessels, each of which encloses a series of tubes. At the end of the travel through each vessel, or effect, the liquor is sprayed into a chamber, where the steam separates out. The liquor passes to the next tube under pump control, while the steam traverses round the tubes, pressure on the liquor being reduced by a vacuum pump. The process is a continuous one, and on completion the concentrated liquor is discharged by a pump from the evaporator to a storage chamber. At this stage it is in a thick, syrupy solution, ready for incineration.

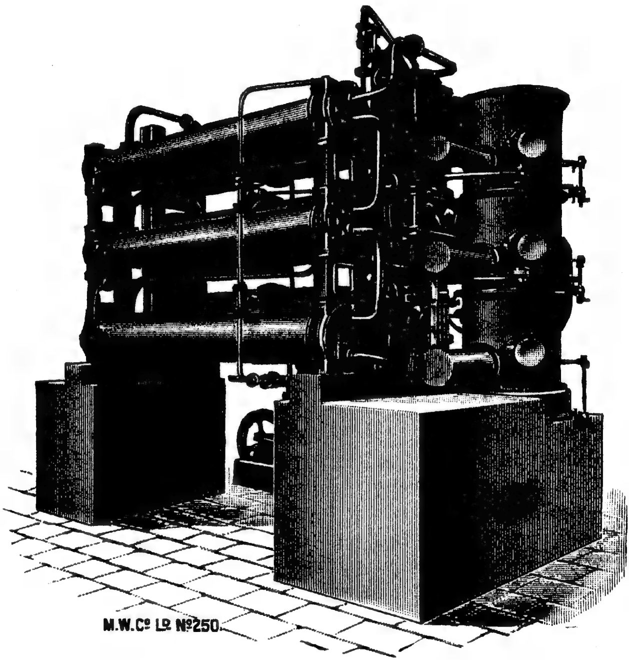

FIG. 15. YARYAN EVAPORATOR
(Mirrlees Watson Co., Ltd. Glasgow)

In the second stage the evaporated liquor is conveyed across to shallow ovens heated by fire, where all the remaining moisture is removed. The heating is continued until the organic matter in the residual mass is burnt off, leaving sodium carbonate as the final product. This substance represents the recovered soda, and requires conversion into sodium hydrate (caustic soda) for re-use in the digesters. To effect this, the sodium carbonate is dissolved out of the burnt ash by the lixiviation system, or in a tank fitted with stirrers, following which the clear liquor is conducted away to an egg-shaped causticizing tank by a pipe devised to prevent the admixture of particles of the insoluble foreign matter. In the causticizer the soda ash is treated with heated water, the solution being maintained in agitation. A quantity of burnt lime is suspended in a cage arrangement fitted inside the tank. As the soda ash liquor reacts with the lime, the latter gradually disappears, to be replaced by a fresh quantity, until the conversion of the carbonate into caustic soda is complete. As a result of this reaction, a thick residue of sludge remains at the bottom of the tank after running off the clear liquor. To remove all traces of caustic from this, a further treatment of boiling with water is applied.

In actual practice, 80 to 90 per cent of soda is recovered, the amount varying according to the class of equipment employed.

Sulphite Wood-pulp. The sulphite process of producing wood-pulp is dependent mainly on the use of coniferous woods. Down to the production of the crushed chips, the preliminary operations are similar to those adopted for soda wood-pulp. The boiling, however, differs materially. Bisulphites of alkaline earth metals, as calcium and magnesium, are generally

employed as the digesting agents, and the liquor is prepared in the pulp-mills in the following manner. Pyrites, or flowers of sulphur, is burned in special ovens under a carefully regulated supply of air, with the object of producing sulphurous acid gas. The gas is conveyed through an iron pipe or brick channel and cooled in a series of lead pipes in water preparatory to entering a tower absorber arrangement. Inside the tower, limestone is closely stacked, with which the acid gas, entering the tower at the bottom and travelling upwards, comes into close contact. To aid reaction and collect the product as solution, water, showered from the top, is constantly percolating through the stacked lime. The gas, plus the water, forms sulphurous acid, which chemically reacts upon the limestone to produce the acid liquor, which is mainly calcium bisulphite, with traces of magnesium bisulphite and free sulphurous acid. In the process, over 2 cwt. of lime and almost 3 cwt. of sulphur is required in the production of 1 ton of air-dry pulp.

The boiling of the crushed wood chips is conducted in large steel digesters, lined inside with brickwork, plaster, or patent composition, to resist the corrosive action of the acid liquor. An average size for these digesters is 45 ft. high by 7 ft. wide, and a complete charge may comprise as much as 20 tons of wood. The boiling is effected at a pressure of about 80 to 100 lb. and continued for nine to ten hours, or under lower pressure for a longer period, according to the character of pulp required. When the boiling is complete, the contents of the digester are blown out into a vat or blow-pit, fitted with a perforated floor, through which the liquor drains away. A washing with fresh water is applied to the mass in order to remove the strong traces of liquor which remain after the first draining,

following which the pulp is screened and passed to the store chests ready for the wet machine manufacture.

A special sulphite pulp of great strength is produced by the Mitscherlich process. Under this system, the wood is slowly cooked for a very long period at low pressure. Approximate data for ordinary mill practice is represented by 48 hours cooking or boiling at pressure not exceeding 15 lb. The necessary heat is produced by steam passed through a lead coil instead of introducing live steam into the contents of the digester, as in the ordinary sulphite process.

The disposition of the waste liquors from bisulphite boiling constitutes a problem which the pulp-makers have not yet efficiently solved. That the contents represent a series of valuable commodities, if profitable means of recovery could be devised, is common knowledge, but, with very rare exceptions, manufacturers find it more economical to dispose of the liquor as sheer waste. Among the various products for which processes have been already patented for conversion of the waste liquor may be mentioned the following: tanning extract, fuel briquettes, binder for brickmaking, dust-laying material, agricultural manure. Perhaps the most successful and profitable venture in the utilization of spent sulphite liquor is that made by certain Swedish mills, and which depends upon the neutralization and fermentation of the liquor for the production of low grade alcohols. Large quantities of the crude spirit are now being annually turned out at a profit by the one or two mills which have overcome the preliminar troubles and expense incidental to the process. The yield is said to average about 15 gallons of 95 per cent alcohol per ton of sulphite pulp.

Sulphate Wood-pulp. In this process of boiling, spruce and pine woods alone are used, the boiling liquor

consisting of sodium sulphate, which is converted into sodium sulphide by ignition with organic matter during the evaporation and incineration. A proportion of caustic soda is combined in the boiling solution in some mills (about one part to three parts sulphate), but the essential feature of the process is the formation and effect of the sulphide. The period of digestion extends up to thirty hours, the object being to produce a pulp with strength as the chief characteristic. The most objectionable feature peculiar to this system is the obnoxious smell created by the formation of sulphur compounds in the waste liquor. Due to this, it is impossible to maintain sulphate pulp mills in anything like close proximity to inhabited districts.

Scandinavian mills largely employ the sulphate process in the manufacture of their kraft brown wrappings, which are renowned for strength, tenacity, resistance to moisture, and finish. For this class of paper, spruce timber, slowly grown under cold conditions, provides the best type of fibre. To secure maximum strength, it is necessary that the fibre should be long, and the woody material rich in lignines. The length of the fibre is preserved by slow cooking and minimum disintegration in the after processes, which treatment also aims at wet hydration of the fibres, thereby agglutinizing the material to some extent. The result of these methods is the ultimate formation of a cohesive sheet embodying strength and tenacity of a very high order. The boiled material, which is of a light golden-brown colour, is only partly washed, in order to preserve a certain amount of the organic substance and colouring matter produced in the boiler.

Before passing to the beaters, it is customary in some mills to treat the material in the edgemill or kollergang, for the purpose of separating the fibres and, incidentally,

inducing a certain amount of wetness into the pulp. In the beaters themselves further colouring matter or stained lye may be added, and the alkaline condition of the pulp rectified or partially neutralized by the application of acid agents. Resin size is employed to bind and stiffen up the sheet, and the beating is continued with the object of inducing wetness or hydration of the fibres, an operation technically known as "milling." This process is aided by the introduction of stone rolls and basalt lava plates in the beaters in place of the usual steel knives and plates.

CHAPTER VI

TREATMENT IN THE BEATER: BEATERS AND REFINERS—LOADING, SIZING, COLOURING

THE process of manufacture has in previous chapters been described up to the half-stuff stage. Having been washed, bleached, and partly de-fibred, the pulp is white but lacks regularity, the fibres not being thoroughly separated. In the case of long fibred material, the individual fibres are not sufficiently reduced to ultimately form an even sheet, nor are they so treated as to impart strength and cohesion to the paper. It is necessary, therefore, to subject the half-stuff to a further treatment, known as "beating," performed in engines known as "beaters." In these engines are also performed the processes of loading, colouring, and sizing.

The beating engine of the standard type is very similar in design and principle to the hollander or breaking engine described in Chapter IV, with the exception of a modification in the arrangement of the knives to suit the especial requirements, and in most cases the omission of the washing roll and sand-traps.

The knives of the bedplate in some beating engines are arranged variously, with the objects of securing the maximum effect of disintegration, and also of aiding the mixture and flow of the stuff. Principally, the special designs in use are zigzag, elbow, knee, and similar angle shapes. The roll and bedplate knives are usually constructed from steel or phosphor bronze

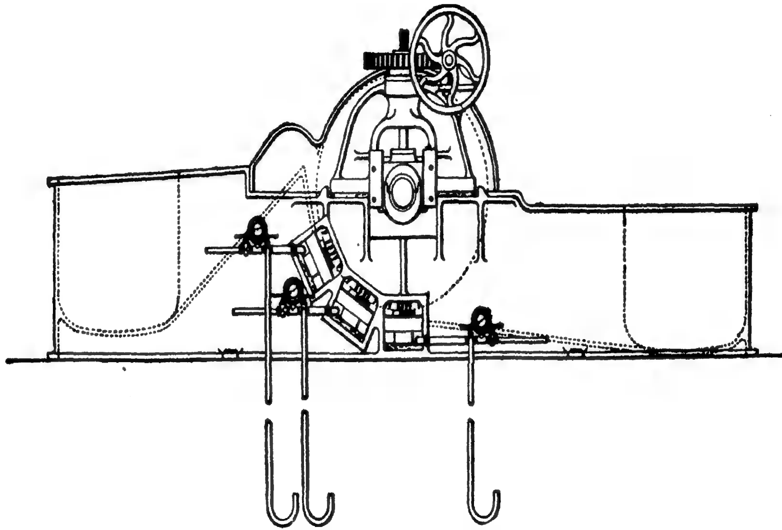

Fig. 16. BEATING ENGINE

(J. Bertram & Son, Ltd.)

metal, but, where it is desired to produce a greasy, well-milled, and tenacious sort of pulp (as in the case of kraft papers and greaseproofs), stone or lava rolls and bedplates may be resorted to. Such rolls would, obviously, be unsuitable where a direct cutting action was desired, as in the case of blotting and other soft absorbent paper. In the same way, dull steel or bronze tackle ("tackle" being the mill term for the beating roll and bedplate knives) would not exercise the required shearing action. It is thus evident that the character and condition of the knives must be considered in relation to the properties required in the ultimate paper. Where hydrated and long-drawn-out pulp of great strength is aimed at, as for loans, banks, and wrappings, blunt tackle would be used, while for writing papers and good printings, the tackle would be between blunt and sharp. In the case of filter, duplicating, and blotting papers, sharp tackle would be used, to effect a speedy reduction of fibre and preserve the property of capillary attraction in the fibres.

It will thus be seen that the beating process is dependent for its manipulation upon a series of factors and features. It is an accepted fact that the beating is the most delicate and important operation in the whole procedure of paper-making. The design and condition of the apparatus and its details; the composition and character of the knives and condition of their edges; the nature and consistency of the material to be beaten; the essential requirements of the paper; these are a few of the factors which must always influence the control of the beating operation. No set rules can be issued as to the precise treatment and length of time required for the various classes of material. As an approximate guide, the following times may be quoted from mill practice—

	Time in Beater.
Linen and cotton for banks and bonds . .	10 to 12 hours
Ragstuff for T.S. writing and account-book papers	5 to 7 ,,
Chemical wood for book-printing . . .	4 to 6 ,,
Esparto and wood for printings and writings	3 to 3½ ,,
Cheap printings and news	1½ to 3 ,,
Soft cotton stuff for blottings	1 to 1½ ,,

It is to be observed that the object of the beating operation is to induce a certain character into the ultimate fibre, which, according to the requirements of the finished paper, must be either: (*a*) bruised, split, teased out and generally mutilated without direct cutting (as in the case of light-weight strong banks); (*b*) separated and reduced in length, but maintained in physical form (as in the case of high-class printings); or (*c*) cut up directly into short tubes (as in the case of blotting, filter paper, etc.).

The influence of the beating treatment upon the behaviour of the pulp when it reaches the wire of the paper-making machine may also be mentioned. If the stuff is beaten sharply with a direct cutting action, it has the tendency to part readily with its water, and is known as "free" or "fast" stuff. Such stuff is suitable for fast-running machines requiring very little suction, and no prolonged dwell on the wire in order to induce it to part with the water which carries the fibres. Pulp which has been macerated and hydrated in the beater is known as greasy or "wet" stuff. On the paper-making machine such stuff holds the water tenaciously, therefore a slower travel and greater suction are required in order to bring the web in sufficiently dry condition to the dandy, couch, and other rolls.

In practice, the beater is charged with water and the half-stuff gradually added, a medium size modern beater holding about ¼ ton of material, while for wood pulp

treatment beaters holding ½ ton are now employed. The roll having been set in motion, it is customary to add, at the outset, a quantity of chemical for the purpose of neutralizing any bleach residue which may still remain in the half-stuff. The substance employed may be either sodium sulphite or sodium hyposulphite, known in the mill by the name of anti-chlor. The engine is, for the first period, run with the beater roll lifted out of contact with the bedplate. As the stuff begins to circulate more readily, the roll is lowered gradually, until, towards the end of the process, it may be lowered sufficiently to exercise a more drastic bruising or cutting action. Before removing the beaten stuff, it is common practice to lift the roll a little in order to brush out or separate the massed fibres. It has in recent years come to be recognized that this finishing operation may more efficiently be performed in a separate type of machine, known as the refiner. The refiner not only brushes out the stuff, but also reduces the fibres to uniform length. Having been thoroughly treated in the beaters in regard to crushing, milling, etc., the fibres are not adversely affected by the reducing action of the refiner. A great advantage of this auxiliary process is that, where several beaters are employed on one furnish, stuff of varying character is apt to be produced, particularly in regard to the length of the individual fibre, rectification of which is effected in the refiner. Trouble at the machine is saved thereby, and a more regular texture, and even look-through, is introduced into the paper.

The newer types of beaters and refiners may be briefly discussed at this stage. The typical beater, as already observed, is of the original hollander pattern, as described in the chapter on Breaking For certain types of material, as in the case of the highest-class

rag paper, the hollander has not been surpassed. With regard to other materials, as wood, grasses, etc., direct advantage may be obtained by the use of patented beating apparatus. The chief objects aimed at in the later types of beater are to save space, economize power, and increase capacity and efficiency.

The Umpherston Beater works on a somewhat similar principle to the hollander, but, instead of making a horizontal circuit round the continuous channel, the pulp travels under the beating roll and makes the return journey under a partition situated beneath the roll. Thus, a considerable saving in floor space is effected. In the latest type of Umpherston, the bed-plates may consist of adjustable segments, each provided with a pressure gauge and water cock to give any desired pressure. The advantage of this arrangement is that the control of the operation is not so entirely dependent upon the skill and experience of the beater man.

The Reed, Taylor, and Acme types of beater are closely related in principle, but in several essential features differ from the Umpherston. Describing the Acme: The stuff makes a subterranean passage as above described, the partition itself being adjustable for cleaning purposes. A conspicuous feature is the position of the beating roll, which, as also in the case of the beaters mentioned in conjunction with the Acme, is raised to a high level, meeting the stuff at the highest point of its travel, immediately upon its ascent from the lower channel or tunnel. The stuff is raised by means of an archimedean screw, or screw propeller, which, in conjunction with the beater roll, promotes the circulation of the pulp.

Quite a different type of beating engine is the "Forbes," which is based on the ordinary hollander

pattern. Instead of the usual continuous channel, two mid-feathers divide the trough up into three channels, in the centre one of which a bucket-wheel revolves and promotes the circulation of the stuff by alternately

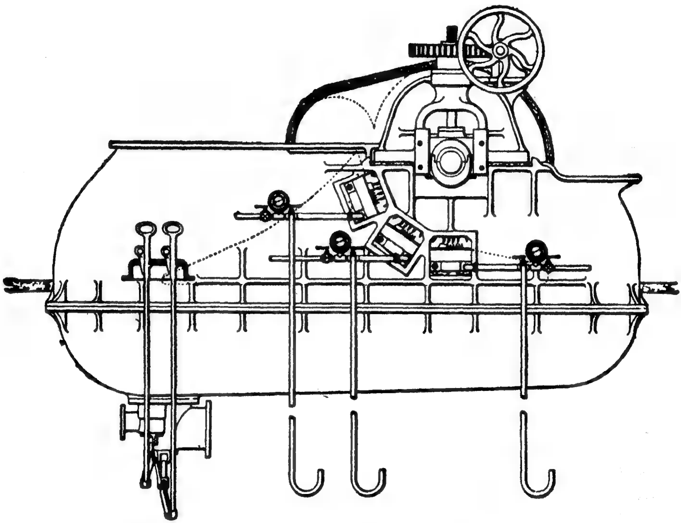

FIG. 17. UMPHERSTON BEATER
(J. Bertram & Son, Ltd.)

lifting it to each of the outer channels. In each of the latter is situated a beater roll. Although covering considerable floor space and consuming an appreciable amount of power, the "Forbes" engine is enabled to treat speedily a large amount of material.

The Masson "Tower" Beater employs a different principle by circulating the stuff upwards and downwards with very efficient mixing and freedom from clotting or settling. For speedy beating treatment of

large quantities of material the "Tower" system is preferred by some of our leading paper-makers.

Of refiners there are now many types, ranging from the original simple refiner to a combination of beater and refiner. The "Marshall" refiner may be considered as the type of apparatus mostly employed. Briefly described, the Marshall consists of a cone-shaped chamber fitted inside the shell with a series of longitudinal bars or knives. The wide end of the cone comprises a fixed disc, also fitted with angle bars, which take a position almost at right angles compared with the cone bars. A similar cone, with corresponding knives and disc end, revolves on a shaft inside the outer cone chamber, the inner disc being adjustable to suit the peculiar requirements of the class of pulp in treatment. In motion, the cone knives reduce the fibres to uniform length, while the discs at the wide end catch the outgoing pulp at a different angle, and by a brushing action perfect the state of separation and disintegration.

The Pearson and Bertram type of refiner performs the same work by means of a central disc revolving between two stationary but adjustable outer discs. The stuff is treated thoroughly between each set of knives, and, to ensure a thorough disintegration, centrifugal force is brought to bear on the pulp in such a way that knotted fibre is rejected for repeat treatment until absolute separation has been effected.

Loading. It has already been mentioned that the processes of loading, colouring, and sizing are performed in the beater. The process of loading consists in adding a mineral clay to the pulp for the purpose of filling up the interstices or spaces between the fibres. Properly applied, loading is not to be regarded in the light of an adulterant, for its functions, in regard to

printing papers particularly, comprise the compacting of the sheets, the production of a pleasant mellow finish, smoothness, and uniformity of surface, and the introduction of opacity and a degree of absorption requisite to the proper acceptance and drying of printing ink. The presence of a good quality loading also minimises the possibility of injury to the type-face. In the case of high-class writings, commercial, and account-book papers, very little mineral loading is employed, the furnish more often including a percentage of suitable brokes, which serves the same purpose and adds to the strength.

The chief types of mineral used for loading are china clay, calcium sulphate, and, more rarely, barytes and agalite.

China clay, or kaolin, is a naturally occurring hydrated silicate of alumina, yellowish to pure white in colour, the yellowness being induced by the presence of deleterious iron compounds. According to quality, the clay contains more or less gritty or sandy particles. It is formed by the decomposition of rocky substances, brought about by long exposure to air and water. In practice, the china clay is mixed to a thin solution with water, and strained before adding to the pulp in the beating engine. The specific gravity of the clay being heavier than fibre, it is inevitable that an amount passes away at the sand-traps, travelling wire, vacuum boxes, etc. In the case of china clay, about 85 per cent. of the amount added to the pulp is retained in the paper.

Calcium sulphate (known also as pearl hardening, satin white, gypsum, and terra alba, according to the various forms, whether precipitated or ground, etc.) is a mineral filler of brilliant colour. It is practically free from grit and imparts a pure tone and even surface to the paper. For these reasons, it is used in the higher

class printings. The mineral is added to the pulp in the form of fine powder, and about 50 to 55 per cent is carried in the finished paper. The precipitated form of sulphate (satin white) is more flocculent than the naturally occurring sulphate, and is thereby better carried in the pulp.

Barium sulphate (heavy spar, blanc-fixe, or barytes) is a mineral of very heavy specific gravity, by reason of which it has a decided tendency to sink from the pulp. Of the amount added, only about 30 to 40 per cent may be expected to be carried in the paper. This, combined with the high cost, debars the use of barytes in most cases, although it is regarded as the most valuable type of clay for coating art and chromo papers. When used in the beater, the prepared powder is mixed with water and sieved to eliminate dirt and foreign particles.

Starch may be regarded partly as a loading material and partly as a sizing agent. Papers made between the eighth and fourteenth century, before the introduction of gelatine tub-sizing, were sized with starch or flour paste. Latterly, starch has been used more in the nature of a filler, or as an auxiliary to the engine sizing process. The high cost of starch and the difficulties of correct treatment preclude its general adoption. The chief functions of starch are to improve the feel by imparting a certain rattle to the paper, to compact the surface, and, in special cases, to harden a paper made from quickly beaten, soft fibres, such as esparto. The effect of adding a small percentage of boiled and swollen starch to the pulp is to give the fibres a gelatinous sort of film, which, under the influence of heat and rolling pressure, as encountered at the drying cylinders, is made to fill up the interstices between the fibres. Thus, the surface is evened up and the paper

itself improved in stiffness and rattle, or feel. Practically, this is the equivalent of prolonged beating, the purpose of which is to induce hydration, and thereby a degree of hardness, in the ultimate sheet. It will thus be recognized that in hydrated pulp, or pulp which is intended for subsequent gelatine sizing, the addition of starch is rendered unnecessary.

Talc has recently been advocated as a suitable filler for printing papers, chiefly by virtue of the high finish which it imparts. Chemically, talc is a double silicate of magnesia and alumina, containing traces of impurity in the form of iron oxide, sand, and limestone. For the purpose of paper-making, the mineral is unsuitable if it contains 2 per cent of ferric salts or more than 3 per cent of limestone (calcium carbonate). With correct manipulation, as much as 85 per cent of the talc added to the pulp may be retained in the finished paper.

Agalite, a species of asbestos, is a type of mineral occasionally employed as a filler or loading. Being of a fibrous structure, and more voluminous than the clays, it both helps the strength and is well retained in the paper. Agalite has a smooth or greasy nature, somewhat like that of talc, and thereby imparts a high finish to paper in which it is used as a loading agent. Chemically, it is a comparatively pure form of magnesium silicate, with but a very small trace of the injurious iron oxide. Although regarded as a valuable type of filler under special circumstances, the high cost of agalite, and sundry difficulties associated with its use, militate against its more general adoption.

Colouring and Dyeing. The stuff, as it appears in the beater, though clean and bleached, is usually of a dull white colour and requires rectification in order to produce the visual effect of a pure or toned white.

This operation is performed in much the same manner that the laundress adds blue powder to whiten linen before ironing. The tone desired in paper may vary from a hard, bluish white to a creamy or pinky cast. To produce these effects, red or blue colouring matter in very small proportions is added to the pulp in the beater. Apart from the whites, the whole range of tints or shades, varying from the azure blue of account book paper to scarlets or blacks in cover stock, is also produced direct in the beating engine while the material is being disintegrated.

For the purpose of rectifying whiteness, the chief dyes employed are ultramarine and cochineal in the finest papers, and such aniline dyes as methyl violet, magentas, and soluble blues in the more ordinary grades. The highest class azure account-book papers are coloured with smalts, ultramarine, or a combination of the two. Where smalts would be too expensive, ultramarine alone is used, although many paper-makers resort to indanthrine (a fast coal-tar derivative), particularly in U.S.A. and on the Continent. For lower class account papers aniline blues are used.

A comprehensive survey of the dyeing of paper pulp is outside the scope of this volume, but the principal classes of colouring matter may be briefly described. The two main branches of dyes or dye-stuffs are organic and inorganic, and each of these may be further divided into two classes, substantive and adjective. The substantive dyes impart their colour to the pulp direct, whereas the adjectives require the aid of a mordant or combining substance. Logwood extracts, bichromates, and certain other inorganic mineral salts come under the heading of adjective colouring matters, inasmuch as the colour is not produced until the affinitive solution is added. The affinitives, or mordants, include alum,

various mineral acetates, tannin bodies, tannic acid, ferrous sulphate, etc.

Inorganic, or mineral colouring matters, comprise, among others, iron buff, manganese browns, chromes, ochres, prussian blue, ultramarine, smalts, red earth pigments, and oxides. Natural organic colouring matters, as apart from the synthetic coal-tar or artificial series, include cutch, quercitron, logwood, fustic, etc., which are seen to be of vegetable origin.

The synthetic organic colours, known popularly as coal-tar or aniline dyes, are now regarded as of the utmost importance in pulp dyeing. For cheapness, ease of manipulation, power and brilliancy of colouring, they far surpass the older types of dye-stuff. Their earlier defects of doubtful fastness are being overcome successfully, but they are still apt to react differently with the various types of fibre. Certain classes of dyes, as the direct cotton series, appear to the best advantage on unsized rag paper. With most of the synthetic dyes, cotton pulp gives purer colours than, say, bleached wood or straw pulp, while these again give superior effects to those obtained on pulp containing unbleached wood. Careful selection of colour and fixing agent must be made in order to secure full efficiency. In this direction, the manufacturers of the various dyes go to extreme pains to make clear the mode of procedure with each individual dye. Certain colours deteriorate in presence of alum, while others benefit; again, the heat of the drying cylinders, unless carefully controlled, adversely affects certain dyes.

One of the chief aims in dyeing pulp with coal-tar colours is to secure a clear backwater at the wet end of the paper-making machine. Unless this precaution is taken, the water which drains or is sucked away from the pulp is apt to hold an amount of the

colour, which thereby runs to waste. This may be prevented, or, in other words, a clear backwater may be obtained, by a correct application of a suitable mordant or by the combination of acid and basic dyes where permissible.

The synthetic or coal-tar dyes may be considered for paper-dyeing purposes as consisting of three classes, direct, acid, and basic. The acid dyes are more amenable to combination with acid affinitives, while the basic dyes give the best results in the presence of tannic agents. Where an acid and a basic colour are worked in combination, the basic dye precipitates the acid dye and renders the ultimate colour fast, while at the same time economising in dye-stuff by producing a clear backwater. Basic dyes are usually more fugitive than the acid series, but produce more brilliant colour effects. Direct or substantive dyes can be applied without a fixing agent, and they are especially useful for unsized papers, like blottings and tissues. They are very fast to light, and have a high degree of colour brilliance and purity.

Modern practice in regard to the application of loading, colour, mordant, and size to the pulp in the beating engine varies, but the most logical procedure is to add the dye before the resin or alum, the latter helping to fix or fasten the colour on the fibre. If sized first, the fibres take on a coating which to some extent resists the action of the dye. Loading is generally added before the colour and helps to even up the tone or shade of the ultimate paper.

The principal coal-tar dyes used in paper manufacture are as shown in the table on page 92.

Sizing. If the pulp is taken to the paper-making machine and converted into paper as it stands at this stage (i.e. boiled, washed, pulped, and containing loading and dye only), the result will be a continuous

sheet of waterleaf. Waterleaf is the mill term signifying unsized paper. Such papers are made for special purposes (*e.g.*, filter paper, blottings, drying and copying paper). The attempt to write upon such paper would

PRINCIPAL COAL-TAR DYES USED IN PAPER-MAKING

	Basic.	*Acid.*	*Direct.*
Yellows	Auramine Chrysoidin Safranine	Metanil yellow Quinoline Naphthol yellow and orange Paper yellow	Sun yellow Titan Paper yellow
Reds	Magenta Grenadine Rhodamine	Eosines Cotton scarlet Metanil red Crocein scarlet	Fast red Benzopur-purine
Blues	Methylene Victoria New blue Paper blue	Soluble blue	Sky blue
Greens	Brilliant green Malachite ,, Diamond ,,		
Browns	Bismarck Vesuvine		Direct Brown
Violets	Crystal violet Methyl ,,	Acid violet	
Blacks	Jet black Coal black	Brilliant black Nigrosines	Direct Black

merely result in the spreading of the ink, owing to the absorbent nature of the sheet. It may be observed, however, that the beating process can be carried out, as in the case of greaseproofs and kraft papers, so as to induce a certain gelatinous character, which acts partially as a sizing. Such beating is, for obvious

reasons, unsuited to the production of printings and cheap writings. If an attempt were made to print upon unsized printing paper, the ink, which contains oil and varnish, would dry mainly by absorption in both downward and outward directions, leaving the pigmentary colour dull and lifeless, and with a tendency for the oily matter to form a halo round the letters. It is necessary, therefore, to treat the pulp in such a way as to render the ultimate sheet proof against direct absorption. A further reason for this additional treatment of the pulp is that the waterleaf is loosely held together and has a limp, spongy feel, two factors which tend toward a short life and less suitable paper, according to its purpose.

The sizing treatment, therefore, is mainly carried out with the object of imparting cohesion of the fibres, neutralising the tendency toward capillary attraction of the fibre tubes, and inducing ink resistance in a requisite degree.

Sizing may be one of two principal kinds, according to the character of paper desired. For printing papers and the cheaper sorts of writings and book-papers, the sizing is performed while the material is still in the form of pulp in the beating engine, and is known as engine sizing. The agents commonly employed to effect the reaction are resin and alum, hence the alternative term, resin-sizing. For high-class writings and account-book papers, gelatine is the sizing agent employed, and the operation is performed upon the made paper. This type of sizing is known under the names of tub-sized (T.S.), animal tub-sized, gelatine-sized, and vat-sized, the term having reference to the tub-shaped receptacle in which the operation was performed in early days. For the present, engine-sizing is the main consideration, the alternative form being discussed

in Chapter VIII. It may incidentally be mentioned that many of the machine-made T.S. papers are previously treated to a weak resin sizing in the beating engine. Hand-made papers never receive this preliminary treatment.

The operation of resin, or engine-sizing, therefore, is performed in the pulp in the beater, after the beating has proceeded for some time, by the addition of resin and, at a later stage, alum. Resin is employed in the shape of a soap, sodium resinate, formed by the chemical reaction between soda and resin. In the mill resin soap is prepared by dissolving the powdered resin by boiling in a solution of soda ash for some hours in a jacketed boiler specially designed to prevent over-frothing. Mill practice in regard to the production of the emulsion varies, some mills preferring to make what is known as a neutral size, others preferring a resinate containing an overplus of resin, known as acid or free resin size. Neutral size consists of a solution in which the soap is a chemically balanced combination of soda and resin, the approximate proportions being one part of pure soda ash to four parts of resin. This solution is of a pale brown colour. Acid size, containing free resin in suspension, is white or creamy in colour, and contains proportionately one part of soda ash to eight parts of resin. The procedure adopted in making white size consists in dissolving a calculated quantity of resin in the soda ash solution, and afterwards stirring in an excess of powdered resin. This type of size is commonly accepted as giving the best results, and requires less alum for precipitation, but care is needed in use to avoid the formation of clotted particles of resin, which would degrade the quality of the paper.

Before adding the solution to the beating engine, the size requires to be strained through cloth or wire, in

order to remove large clots, foreign particles, or other impurities. After the resinate has become thoroughly incorporated with the fibres, alum is added to the beater in the form of aluminium sulphate, the older practice of using potash alum (which contains only 36 per cent of aluminium sulphate) being largely discontinued, owing to the purity, cheapness, and ease of manipulating the sulphate. The mill term "alum" still persists for the later form of chemical. The amount of aluminium sulphate to be added is calculated according to the strength and percentage of resin employed, a preliminary alum treatment usually being accorded to neutralise salts in the water before adding the resin. Excess of alum is usually allowed for this purpose, as also in the case of dyed pulp, which has an affinity for this chemical as a mordant or fixer. Certain types of dye are, however, adversely affected by alum, as, for instance, ultramarine.

The result of adding alum to the pulp containing the resinate is to effect a chemical and physical reaction, the alumina to some extent taking the place of sodium in the soluble sodium resinate to form a finely divided precipitate of insoluble aluminium resinate. Much doubt exists among authorities as to the true chemical reaction which actually occurs between the alum and resin on the one hand, and the alum and cellulose, or fibre, on the other. Probably the most accurate view to take, according to present evidence, is that the excess of alum generally added, decomposes the previously formed alum-resinate to liberate free resinic acid and form a dibasic salt of alumina, the free resin in an exceedingly finely pulverized state thereafter accomplishing the sizing. As it exists before precipitation, the free resin is too coarse for the delicate operation it is called upon to perform.

It is a recognized fact that the hot drying cylinders at the finishing end of the paper-making machine perform a useful function in completing the sizing efficiency of the paper. The particles of resin which are present in the form of an enveloping film on the fibres, become fused, spread, and hardened by the heat and rolling pressure, thus enabling the paper to offer a better resistance to ink or water penetration.

The normal application of size to printing papers constitutes about 2 per cent of resin and 4 per cent of alum.

Casein Sizing. In recent years, casein has found some use as an auxiliary sizing agent, mainly in the U.S.A. and on the Continent, for cheap papers. The chief function of casein is, however, more in the direction of a substitute for glue in the coating of art and chromo papers, under which heading its nature and properties are more fully described (Chapter X).

In the process of sizing, the casein is allowed to soak for some hours in six to eight parts of warm water containing a trace of alkali, the solution being maintained in agitation for the greater part of the time. To effect dissolution of the casein, powdered borax is added. When thoroughly dissolved, the solution is strained, and a calculated quantity added to the pulp in the beater in conjunction with a reduced amount of the usual resinate. The proportions are about half and half, the percentage of resin being half of that usually applied in resin sizing. Alum is subsequently added to effect precipitation of both sizing agents, the casein imparting to the ultimate sheet an improved feel and rattle, closely approaching that conferred by animal tub-sizing. The chief deterrents to a more universal employment of casein are the high price compared with resin, and the possibilities of degraded colour.

CHAPTER VII

THE PAPER-MAKING MACHINE

On completion of the treatment in the beater, the stuff is ready for conversion into paper on the paper-making machine. There are several types of machine, but for the purpose of manufacturing writing, book, and printing papers the Fourdrinier machine is universally employed. The starting-point of the Fourdrinier is at the stuff chests, which are large vertical tanks, devoid of corners where fibre could lodge, capable of holding upwards of half a ton of pulp. The pulp is conveyed to the stuff chests from the beaters or refiners through a wide pipe. To effect a thorough mixture of the stuff, which may represent the output of several beaters, the chests are fitted with vertical or horizontal stirrers or paddles, which slowly rotate and mingle the stuff. Dilution to a consistency suitable to the class of paper being made is partly effected in the stuff chests, of which there may be one or two, according to the capacity of the machine, etc. Accurate dilution of the stuff is usually completed by an intermediate stuff box, or regulating box, fitted with a float connected with a water tap. Over-thickening of the pulp causes the float to rise and allow inflow of water, until sufficient dilution allows the float to retire and thus shut down the water supply.

To avoid the possibility of knotted fibres, grit, dirt, etc., appearing in the finished paper, the pulp, after leaving the stuff chest, encounters a series of contrivances disposed between the stuff chest and the travelling wire of the paper-making machine. In the case of high-grade papers, the pulp, as it is pumped from the stuff-chest, flows over a sandtrap device,

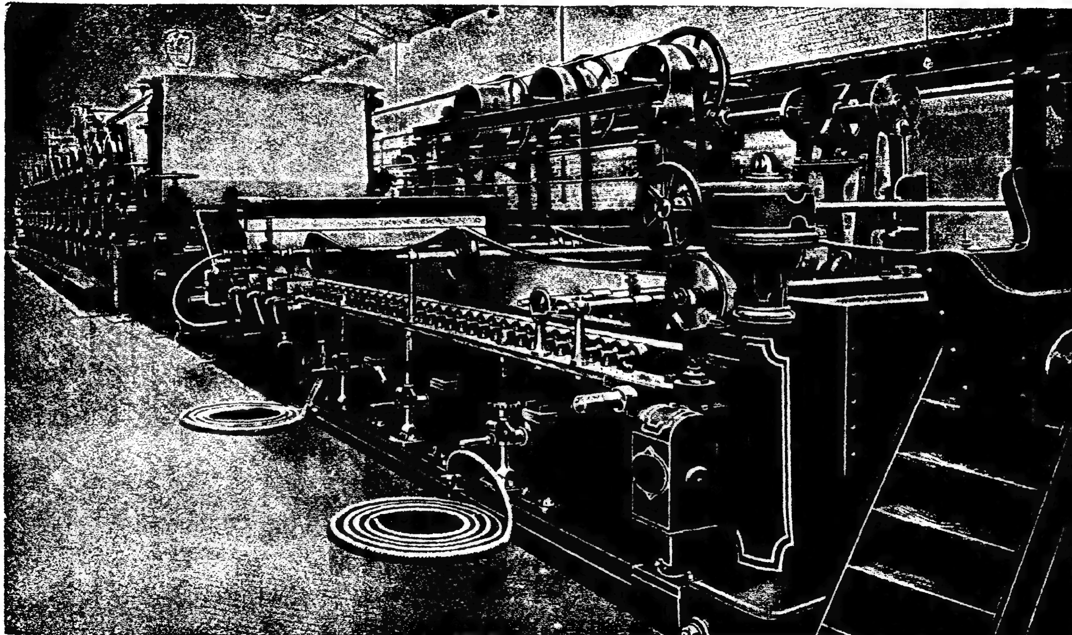

FIG 18. FOURDRINIER PAPER-MAKING MACHINE

which, in the manufacture of news-printings and common papers, is unnecessary. The sandtrap consists of a more or less long corrugated channel, with riffles set at an angle of 45°, which collect and retain the sand and heavy particles as they fall by reason of heavy specific gravity. Usually the recesses in the sandtrap are felt-lined, to make a secure hold on the foreign matter.

From the sandtrap, the pulp passes onward through the strainers, of which there may be two or three, arranged to prevent the intrusion of coarse fibres, splinters, knotted stuff and foreign matter. The evenness and clearness of the ultimate paper largely depends upon the efficient working of the strainers. With the idea of securing maximum effect, a number of different types of strainer have been introduced from time to time, but each of these varies only in some detail from the two principal classes of strainer, viz., the flat vibrating or oscillating strainer, and the revolving strainer of cylindrical or related shape. In either case, the strainer is fitted with plates containing narrow slits all over the surface, through which the pulp is drawn by suction. To facilitate easy passage of the pulp after it has entered the aperture, the slits widen inwards to a Λ shape. The coarse stuff and foreign matter is refused passage, and, according to the make of strainer, various methods are resorted to for collecting and washing away the rejection for further treatment.

The most recent addition to the forms of equipment for cleansing the pulp, removing impurities, foreign matter, clumps of fibre, etc., is the "Erkensator," a type of centrifugal separator, situate at the commencement of the wet end part of the paper-making machine. The Erkensator is a small engine, and is usually arranged

in battery grouping as substitute or auxiliary to the sand traps and strainers. In order to secure the fullest measure of refinement, the pulp requires to be in very dilute condition. By centrifugal force, heavy and light impurities are separated and driven into various collecting pockets in the rotating cylinder, while the cleansed pulp passes through to the wet end wire. In practice it is proved and accepted that, by the use of the Erkensator, cleaner, stronger, more regular, and better looking paper is made at a negligibly higher cost of production.

After leaving the strainers, the refined pulp may either pass through a pipe direct to the wire of the paper-making machine, or, according to quality, it may be conveyed to a small hog or mixing chamber fitted with stirrers which serve the purpose of maintaining the fibres in a thoroughly commingled state.

The pulp flows on to the travelling wire over an apron cloth of waterproof material, the function of which is to provide the connecting link between the breast board and the wire. To prevent the overflow of the pulp, the apron extends across the full width of the wire and is turned over at the sides.

At this stage the fibres tend to dispose themselves in a direction parallel to the onward flow of the pulp. Partly to neutralize this tendency, but more particularly to control the flow of the pulp, a gate or slice is arranged just beyond the apron, which checks the flow and causes the pulp to form a head behind the slice. The latter consists of two overlapping brass plates, adjustable in width and height to suit the width and thickness of web being made. As the pulp emerges from beneath the slice, it is, by virtue of the higher level or head behind, forced to accommodate itself to the full width set for the web. The controlling factor in web width

is the deckle straps, without which the pulp would simply overflow the wire.[1]

The deckle straps are endless india-rubber belts, about 1 in. square, which run on grooved pulleys, one pair at the commencement of the wire and the other pair situated in a position further along, at which point the water has left the web sufficiently for the latter to need no further width control. The pulleys at the commencement of the travel are connected with the slice and apron in such a manner as to allow a sort of trough ot variable width to be arranged according to the adjustment of the deckles. Thus the flow of pulp width-ways is confined to set dimensions. The deckle straps, as they take the outward journey, sit flat and tight against the wire, making it impossible for the pulp to creep beyond the defined width.

The endless travelling wire of the Fourdrinier machine governs the width of web which can be produced. Modern fast-running news machines exceed 200 in., while the more usual widths of wire for machines making good class writings and printings are within the region of 100 in. The length of wire ranges between 30 to 50 ft., the traverse starting from the breast roll and reaching the couch rolls, when the wire makes its return journey round the couch roll and back to the breastroll. The speed of travel varies greatly according to the design of the machine and the class of pulp in treatment. High-speed news machines turn out 600 to 900 ft. per minute, while fine paper machines range from 60 to 200 ft.

The wire itself is of fine mesh, varying between sixty to seventy strands to the inch. In action, the wire is held taut by adjusting the rolls on which the wire

[1] The term "web" refers to the pulp as it forms the endless sheet of paper on parting with its surplus water.

makes its return journey. The surface is supported and kept level by a continuous series of small-diameter rolls beneath the wire.

The pulp flows on to the wire in a very much diluted state, often containing almost 99 per cent. of water. It is essential that the bulk of this water should be removed before the web reaches the end of the wire, at which stage it is necessary for the web to make a short travel without support. As many papers require to be watermarked (a process performed before the web reaches the end of the wire), there is additional reason for having the water sufficiently extracted to leave the dandy roll free to make a lasting impression.

The extraction of the water is performed by two principal agencies, both working on the vacuum suction principle. In the first place, a series of brass rolls, running in close contact with each other, is arranged beneath the travelling wire, the periphery of each roller or tube touching the under surface of the wire. When the latter is running with a coat of pulp, a series of small vacuums is created by the disposition of the rollers beneath. Thus a large amount of water is withdrawn from the pulp. Apart from this, the rollers perform the aforementioned function of supporting the wire.

The prime agent for removing surplus water from the web is the suction box, of which there may be two or more, situated towards the end of the wire. The suction boxes, which are really water troughs, run across the full width underneath the wire and in close contact. To effect thorough suction they are maintained with a full supply of water and are worked by powerful pumps. The surface of the box is either mahogany, brass, or lined with vulcanite. The chief sources of danger are rapid wear of the boxes, or, on

the other hand, damage to the wire. To a large extent, this is obviated by the employment of the newly-introduced suction couch roll, which, as will be later explained, eases the work of the suction boxes. The suction boxes are arranged so that the intensity of the suction increases at each box, the first one acting more gently than its successors. Too sudden and powerful an action would tend to create breaks at a later stage. Even after passing the suction boxes, the web still remains very moist, and requires the pressure of the couch rolls to further eliminate surplus water. Before considering this part of the Fourdrinier machine, something must be said in regard to backwaters and the shake of the wire.

Obviously, there is some escape of fibre, loading, etc., with the backwaters which leave the web. Modern mill practice makes use of sieve devices, known as pulp-savers or save-alls, for recovering the products which, until recent years, ran away with the waste water.

Concerning the "shake" of the wet end wire, in relation to the formation of the web, it has already been pointed out that, at the commencement of the wire, the pulp is quite liquid, with the fibres held in a state of suspension. The tendency of the fibres is necessarily to dispose themselves head on to the flow of the pulp. Unless counteracted to some extent, the result of this tendency would be to produce a paper with the fibres laying parallel to each other. Such a paper would be deficient in strength in one direction. To effect a thorough cohesion or felting of the web, the method adopted is to cause the fibres to intertwine or "felt" with one another, by imparting a side-shaking motion to the wire of the machine, in a direction at right angles to the travel. Obviously the value of the shake will

be greatest at the point at which the water commences to leave the wire, when the fibres are just preparing to settle down. As the web assumes a more settled condition, due to the water abstraction, the influence of the shake becomes less definite. For this reason, the motion is graduated from a fairly vigorous side-shake at the commencement to a barely perceptible agitation as the web approaches the suction boxes. Practically the first 6 to 12 ft. of the wire decides the lay of the fibres, and to some extent the evenness in strength across both directions of the ultimate paper.

To further facilitate the manipulation of the web in regard to the influence of water and the shake, the wire is usually disposed at a sloping angle, running downwards toward the suction boxes. According to the speed of the machine, the pitch may vary, being adjusted to allow a longer or shorter dwell of water. The character of the pulp has also to be considered in relation to the pitch of the wire, fast or greasy stuff holding its water more tenaciously than free stuff. For high speed production of newsprint the downward slope of the wire is essential in order to retain water sufficiently to compose an even web. In the case of strong writing papers from well beaten rag fibre the slope of the wire to the suction boxes may take a slightly upward direction.

Situated between the suction boxes, at a point where the web still remains moist, but not wet, is the dandy or watermarking roll. The function of the dandy, apart from impressing the watermark name or device, is to even up and close the fibrous surface of the web. The dandy roll consists of a light skeleton drum covered with wire of fine mesh. The wire may be of the ordinary woven design, as for wove papers, or containing spaced ribs with close cross lines, as in the case of laid papers. On this wire covering is stitched or soldered the name

or device, worked in wire. Whether a watermark is employed or not, the dandy is used for the aforementioned purpose of evening or closing up the surface of the web.

It is to be observed that the travelling wire of the paper-making machine is always of woven texture, irrespective of the type of paper being made. Whatever

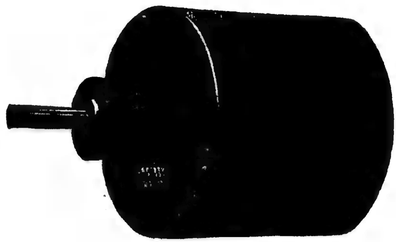

FIG. 19. END OF WOVE DANDY ROLL

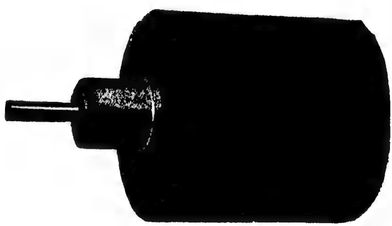

FIG. 20. END OF LAID DANDY ROLL

design in the way of wove, laid, linear, or other watermark is required must be imparted by the dandy. Consequently, machine-made papers, although laid watermarked, invariably show traces of the woven machine wire on the under-side, the dandy roll depending entirely for its effect upon a light, riding motion on the upper surface of the web.

The actual translucent effect which constitutes the

watermark is secured by the raised wire device on the dandy pushing away a corresponding part of the fibre in the web, thus thinning it in those parts.

At the end of its travel with the wire, the moist web comes into contact with the couch rolls, the wire itself making the return journey round the lower roll. The web, after further extraction of water by rolling pressure, is sufficiently dry to continue its travel unaided to the wet press.

The couch rolls consist of two large, hollow, adjustable cylinders, the upper one of which is clothed in a felt jacket and set back slightly towards the wet end. The felt is kept clean and free from bits of stuff by a brush, which reacts against the revolving roll. The action of the rolls in removing surplus moisture is mainly that of adjustable pressure from the upper roll.

In recent years, considerable progress has been made in the direction of employing a suction cylinder in place of the former couch rolls, thus to a large extent eliminating the pressure system in favour of suction and pressure combined. The principal advantages of the suction rolls are claimed to be: saving of the wire, less wear and tear on the felts, removal of a greater volume of water, and easing of the work to be performed by the suction boxes. In addition, a more even-sided paper, with low degree of stretch, and improved surface, is possible, while fuller effect is given to the watermarking, owing to the absence of crushing pressure. The principal types of suction couch cylinder in present use are the Millspaugh and the Margalt, each depending upon the principle of drying the web by suction and the forcing of air through the paper by vacuum. Instead of the two rolls necessary to the ordinary couching procedure, only one cylinder is employed in the case of the above-named patents. This cylinder is fitted with

a perforated case or shell which rotates, while the suction box, fitted inside, remains stationary and in adjustable contact with the shell. The suction box, or boxes, are connected with a powerful pumping arrangement, which is capable of maintaining uniform vacuum in volumes of air and water By this means water is abstracted and large and constant volumes of air drawn through the wet web passing over the roll, thus removing the bulk of the moisture.

On leaving the couch rolls, the web of paper encounters the wet presses, of which there may be two or three sets, according to the class of machine. Each wet press consists of a pair of cylinders, adjustable to provide any requisite degree of pressure for the purpose of still further extracting the moisture which persists in the web. In its passage through the wet presses, the paper travels in contact with an endless felt blanket, known as the wet-felt, owing to the condition of the web at this stage of the manufacture. The impression of the felt texture caused by pressure on the web at the first wet press is corrected at the second by reversing the side of the web, so as to bring the impressed side against the roll. The third wet press practically removes the remaining traces of felt texture.

For the purpose of removing any fragments of pulp or paper that may adhere to the web after its passage through the couch rolls, a blunt blade, called the doctor, is fitted on the top of the press roll, where it rests against the travelling web and stops the passage of the bits of waste.

The web of paper at this stage has lost most of its former tenderness, and to some extent has become evened up. Though still damp, it is in a suitable condition for making the traverse of the drying cylinders in company with the endless dry felts. The latter are

effective in keeping the web tight and even, thus eliminating the danger of cockling. The number of drying cylinders on the Fourdrinier varies considerably, according to the type of machine. On fast-running news machines, there may be as many as thirty-six drying cylinders, whereas book and fine printing machines rarely embody more than twenty. The diameter of the cylinders ranges between 4 and 5 ft., for common practice. Usually, the cylinders are arranged in series, or batteries, with a pair of small diameter steel smoothing rolls, heated, working near the end, for the purpose of facilitating even-sidedness of the web. The drying cylinders themselves are steam heated on a graduated plan, the temperature reaching its maximum toward the end of the series. To remove the water of condensation which is constantly forming within the cylinders various methods are adopted. Chiefly, they depend either on a syphon system, bucket arrangement, or a spiral scoop or conduit which runs the water away through the hollow journals of the cylinders

To accommodate the inevitable shrinkage of the web occasioned by heated drying, the cylinders are graduated in diameter, and with the same object the power driving is arranged in section.

Although dry and smooth, the web is rarely sufficiently well finished for its purpose. The requisite degree of smoothness is imparted by stacks of cylinders known as calenders, of which there may be from one to six, or even a larger number on certain machines. After leaving the calenders, and before reeling up, the web usually passes through a pair of cooling rolls of chilled steel which help to condition it preparatory to being wound up in the solid reel. Alternatively, the same treatment may be imparted by a spraying or damping apparatus. News and common printings are

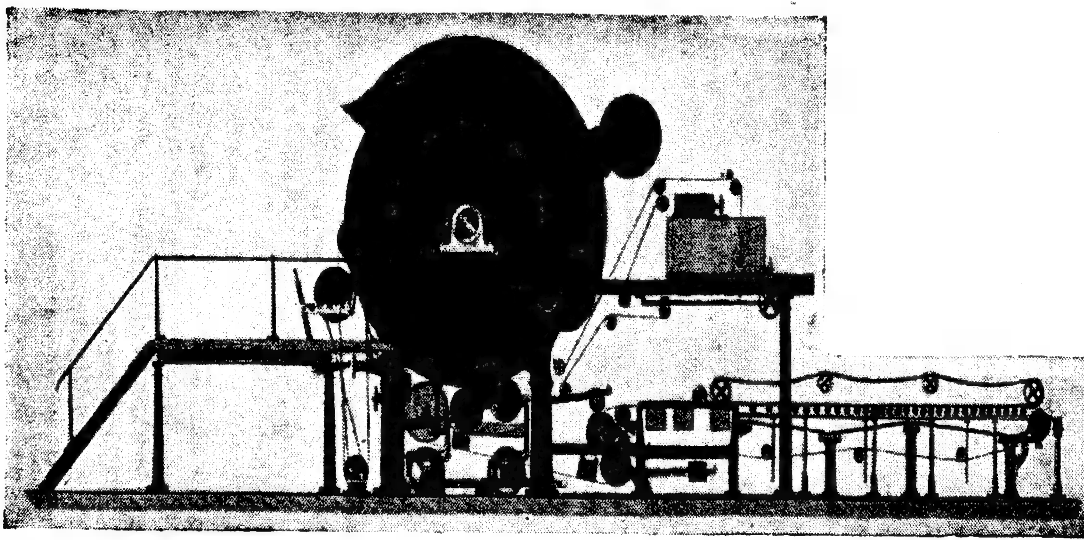

FIG. 21 SINGLE CYLINDER PAPER-MAKING MACHINE

finished off completely, and in some cases slit to size, on the Fourdrinier machine, the reels, as they are finished, being ready for despatch. Better class papers receive their finish apart from the paper-making machine, as will be shown in the next chapter.

In describing the cylinders, passing reference was made to the shrinkage of the web of paper. The influence of shrinkage is a factor which has to be taken into account throughout the whole process of paper-making. According to the class of paper being made, the actual shrinkage may reach as high as 5 or 6 per cent. To allow for this, the deckles are set with ample margin for contraction plus trimming. The watermark device on the dandy roll is also spaced to allow sufficient shrinkage to bring the ultimate marking into correct positions in the cut sheets. The driving of the machine is arranged in section, so that the speed is adjustable for progressive developments of the web, and, as before-mentioned, the drying cylinders are graduated sufficiently in diameter to avoid undue tension on the drying paper.

Tub-sizing on Machine. In the case of the cheaper grades of tub-sized account-book and writing papers, it is usual to perform the sizing operation on the paper-making machine. For this purpose, a long vat is situated between the two batteries of drying cylinders. The web, after leaving the first series of cylinders, is carried through the vat for some distance with its under surface in contact with the warm gelatine size. This contact travel enables the air to escape and ensures a more thorough permeation of the web for the remainder of its journey, which is performed in total immersion in the solution. On emerging, the excess size is squeezed away by the action of a pair of rolls, following which the web passes through the remaining drying cylinders, and is reeled in the usual way.

The more approved plan, as carried out on the better class of papers, is to make the sizing an operation altogether apart from the paper-making machine. By this means, a more thorough penetration, stronger sizing, and more efficient drying is secured. The web, after sizing in the manner indicated (*see* Chapter VIII) is reeled and allowed to stand until it has become thoroughly saturated by the gelatine. It is then dried over a long continuous series of light skeleton drums, built up with spars, each drum containing a fan device, which circulates air in a direction opposite to that in which the web is travelling. The process is known as air-drying, and approximates more closely to the process of natural loft-drying adopted in the manufacture of hand-made and the very best machine-made papers.

For the manufacture of thin M.G. wrappings, M.G. poster printings, and other thin papers finished one side only, a machine of different construction to the Fourdrinier is employed, known as the M.G., Single Cylinder, or Yankee (*see* Fig. 21). This machine comprises the usual equipment of the Fourdrinier up to the couch rolls. Instead of travelling thence to the drying cylinders, the web leaves the couch rolls on an endless felt and passes to a single hollow cylinder of large diameter, usually about 9 or 10 ft. This drying cylinder is of polished steel and is steam heated, a combination which serves both to dry the paper and to give a "Mill Glazed" finish to the side of the web in contact with the surface. A single revolution suffices to dry the web, which is then wound on the reel in the usual manner. Meantime, the endless felt passes through a washing tank containing a device for cleaning the felt and opening out the pores which have become clogged and soiled through contact with the soft, moist web.

For the manufacture of boards, quite a different type

of apparatus is employed. In this case, the strained pulp is carried to a tank or vat in which a cylinder or drum revolves on a shaft. The drum, which is covered with a close mesh wire, dips in the pulp and, as it rotates, picks up a surface film of pulp, the water being drawn through the wire by suction into a syphon arrangement, which conducts it away. The fibrous film is transferred from the cylinder to a wet felt, and carried to a set of press rolls, which squeeze out the surplus water, the web then being reeled on the upper roll. When a desired thickness has been obtained, the sheet is slit through and piled ready for pressing and ultimate drying and finishing.

Alternatively, a series of vats and cylinders may be employed, the webs being run together to form the desired thickness. In the moist state, the webs are capable of forming a thick cohesive board under rolling pressure. In the same manner, duplex coloured boards are formed by running two coloured webs and, if necessary, a white or grey centre.

CHAPTER VIII

HAND-MADE PAPER

THE process of making paper by hand, or, more correctly, the formation of the actual sheets, is performed in the same manner to-day as it was some centuries ago. Any developments which have taken place have principally been associated with the production of the pulp and the methods and apparatus used in sizing. The stages leading up to the actual production of the pulp may be identical in procedure, whether the pulp be intended for high grade machine-made or hand-made paper, excepting, perhaps, that in the case of the former a small percentage of resin size may be added to the beater.

For obvious reasons, the hand-made process is associated only with the very highest grades of paper, hence scrupulous care is exercised in the selection and treatment of all materials. The rags are cut by hand, to ensure perfect cleanliness and to enable the maximum degree of control to be maintained over the sorting operations. To the same end, the material is wet picked after boiling. The water supply is of the utmost importance, and a casual survey of the situation of the English mills reveals the fact that abundance and purity of the water and freedom from smoke or impure atmosphere have been main factors in the selection of the various sites.

Briefly recapitulating the procedure usually adopted in producing pulp of the character requisite to the production of hand-made paper, the cotton or linen rags and threads are graded in quality, according to whether

old or new, white or coloured, and degree of impurity. They are afterwards cut by hand to small pieces and treated in the willow duster, which dusts and shreds the material and eliminates the dirt to some extent. From this engine the rags are transferred to the boiling kier, in which they are cleansed and softened by regulated boiling with caustic soda under agitation. They are finally washed and removed from the kier, after which they require to be wet picked in order to still further remove solid impurity and foreign matter. Consequent upon this comes the washing and breaking process, performed in a similar manner to that explained in Chapter IV. On the termination of the breaking in, bleaching is accomplished, still in the same engine. After this treatment, the half-stuff is transferred to the old-fashioned hollander for beating to pulp. Here, the necessary antichlor is added, while at a later stage, if tinting is required, the dye is added. In the case of account-book papers, the azure or blue shade is imparted by the use of smalts, or, in the case of second quality, by a mixture of smalts and ultramarine. Smalts is a silicate of cobalt and, as a colour, is absolutely permanent and fast to light, heat, impure air, acids, etc. There are few machine-made papers dyed with smalts, owing to its high cost and heavy weight, the latter causing the mineral to sink rapidly to the underside. Thus, under the influence of the shake and vigorous suction, a large proportion of the smalts would be lost in the case of machine-made papers. In moulding the sheets by hand, it is impossible to lose any of the dye, although its high specific gravity undoubtedly causes a distinct difference in shade between the top and under surface of the sheets. As a colouring matter, ultramarine is cheaper and gives rise to a purer and more attractive shade of blue, but the effects of alum, acids,

and heat are deleterious to the colour, alum paling it considerably, while acids destroy it altogether.

After being beaten sufficiently, the pulp is conveyed to the chests ready for conversion into paper, sheet by sheet. The making of the sheets through the first stage requires the aid of a vatman and a coucher. The pulp is discharged into a vat of rectangular shape, with rounded corners and sloping sides, which cause the vat to narrow at the bottom. Inside the vat, near the bottom, is fitted a hog, or stirrer, for the purpose of maintaining the fibres in continual agitation. The speed at which the hog rotates is carefully controlled, as it has a direct bearing upon the flow of stuff over the vatman's mould. The stuff itself is slightly heated, tepid, in fact, to facilitate removal of the water from the mould. For the purpose of picking up the pulp and forming the sheet, a mould and deckle is employed, the size of the mould conforming to the size of sheet to be produced. Essentially, the mould consists of a frame of wood (usually mahogany), ribbed across the narrow way with wood spars, and covered on the top with a coarse wire support, over which rests the fine mesh wire cloth. The wire pattern must, obviously, conform to the texture of the papers to be made (i.e. whether wove or laid), and whereas the cloth described would correspond to a wove paper, the arrangement of the top wire must be differently arranged for a laid paper. In this case, a series of wires are mounted on the wooden ribs of the mould, about 1½ in. apart, running the narrow way of the mould. At right angles to these, a close series of long wires is stitched with fine wire, about fifteen or twenty to the inch, the whole being supported by the coarse wire cloth and wooden wedges. The wires impress the wet pulp and form thereon the wove or laid pattern. In a similar manner any required

watermark device may be arranged in wire and sewn on to the mould wire, thus enabling the simultaneous formation of texture pattern and watermark to be performed.

To prevent the pulp from overflowing the mould, a deckle, or loose rectangular frame, made of mahogany, with bevelled edges, is placed on the mould before dipping for each sheet. The selection of the wood and preparation of the deckle is a matter calling for skill and experience, as constant immersion in water and standing overnight would tend to warp away any but the most carefully made deckle.

The mould and deckle are handled by the vatman, who, standing in front of the vat, fits the deckle on the mould and makes a dip at a correct angle. According to the thickness of sheet to be made, a definite amount of pulp requires to be picked up on the mould, the gauging of which is entirely a matter of personal experience. As the mould is drawn out of the vat, a temporary vacuum is created, which draws away some of the water. On leaving the vat, a dexterous side shake is given to the mould; meanwhile, a slight ripple runs forward over the surface of the waterleaf and is tipped off by the vatman at the extremity of the mould. Immediately upon this, a slight, straightforward shake is given, which perfects the felting or intertwining of the fibres, thus imparting to the sheet the necessary cohesion and strength. Throughout this process, which occupies but a matter of seconds, the superfluous water is draining away from the wire, leaving the formed sheet of waterleaf in a condition which admits of its transference to the wet felt.

As soon as the sheet is formed, the vatman lifts his deckle, transfers the mould across a board to the coucher, and fits the deckle on the mould used for the previous

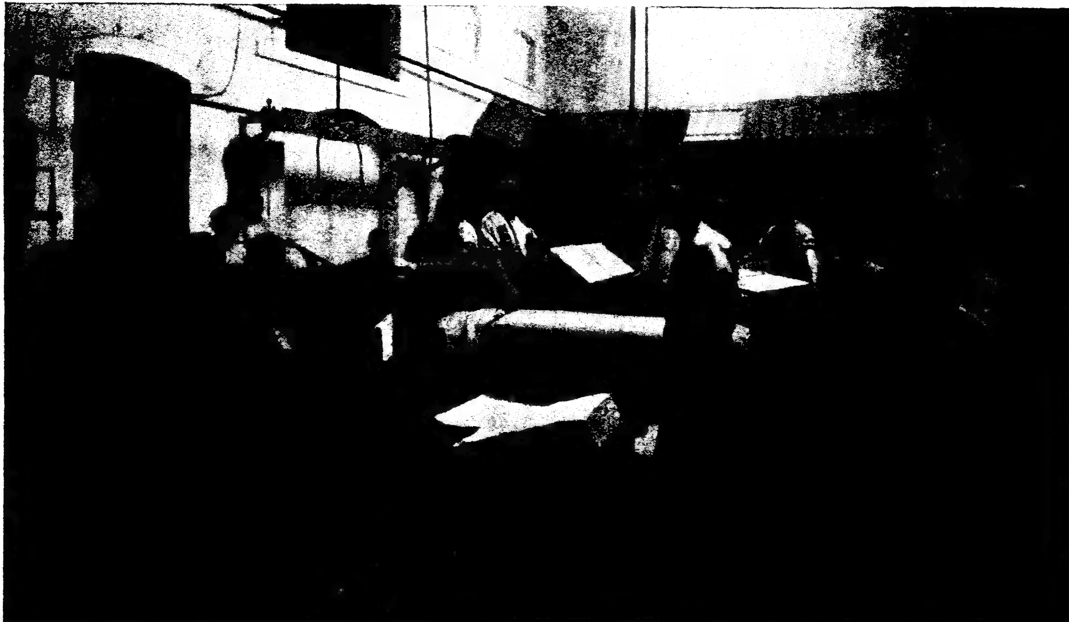

FIG. 22. THE MAKING OF HAND-MADE PAPER

sheet. The coucher turns the mould over and, by a skilful movement, deposits the sheet of waterleaf in perfectly flat condition on to a wet felt slightly larger than the sheet. As the process continues, paper and felts are piled alternately one above the other until a post of about eight quires is obtained. At this stage, the pile is conveyed to a powerful hydraulic press and submitted to tremendous pressure, as a result of which the greater proportion of excess moisture is removed.

On removal from the press, the sheets are stripped from the felts by an assistant, known as the layer, and piled one on top of the other in preparation for a further pressure, to remove more moisture and eliminate the felt marks. Meantime, the felts are washed and returned to the coucher. After standing in the press for some hours, the sheets are taken out and either re-assorted for further pressure or passed direct for drying. This operation is conducted in special drying lofts, maintained carefully under regulated temperature and atmospheric humidity, the sheets being hung in small batches over cow-hair ropes, of which a large number are arranged in rows, along, and up and down. Cow-hair ropes are essential, as other materials have a decided tendency to create stains. The sheets are allowed to hang for a considerable period, during which they are changed in position to allow the inner sheets to be subjected to equal conditions to the outer ones. A considerable amount of shrinkage occurs in the sheets during loft-drying, resulting in a thoroughly matured, well-formed, and tenacious paper.

Having been thoroughly seasoned, the sheets are at this stage gathered for the sizing process. Some hand-made mills make their own gelatine size, while others depend upon the ready-made product. The materials used in size manufacture are wet and dry hides, and the

rejects and refuse from tanneries, comprising hoofs, horns, bones, clippings of hides, etc. These are first cleansed and softened by washing in water, after which they are transferred to a copper pan, covered with water, and heated by passing steam into an outer jacket. After ten to fifteen hours treatment, the animal matter is almost wholly converted into gelatine, an amount of fatty matter collecting on the top to form a scum, which is skimmed off. The solution itself is filtered through felts to remove insoluble impurity, and alum, to the extent of about 10 per cent on the weight of the gelatine, added to condition the solution, prevent putrefaction, and help the necessary character of ink resistance. Occasionally, a quantity of white curd soap is also added to the solution, before the alum, for the purpose of helping up the finish of the paper.

For storage purposes, the gelatine is allowed to set to a firm jelly, quantities of which are taken as required and dissolved up for use in the sizing vat. This consists of a long trough, through which the sheets slowly travel, being fanned out, or partly separated from each other, as they are fed in by a girl. For a short distance, the sheets keep to the surface, with their under-sides in contact with the solution, after which they travel in full immersion. By this method the expelled air has a ready means of escape, thus facilitating the subsequent penetration of the size. The solution itself is kept warm by a steam coil or jacket, the temperature requiring careful control, as it is directly related to the strength and viscosity of the size. High temperatures reduce the viscosity of the gelatine and permit more rapid but less efficient penetration. The stronger the solution, the greater viscosity and consequent less speedy penetration, necessitating a slower or longer travel of the sheets.

At the conclusion of the journey through the sizing

vat, during which the traverse of the sheets is guided by felts and rolls, a squeezing nip is imparted to remove excess size from both sides of the paper. The sheets are then submitted to a further stacking, parting, re-stacking, and loft-drying, at the conclusion of which they are again pressed and passed forward for plate-glazing. In some cases the sizing, pressing, and stacking operations are repeated before resorting to the plate-glazing finish. This operation consists in placing sheets of the paper between plates of polished copper and passing a small pile of such forward and backward under the pressure of a powerful pair of steel rollers. The sheets and plates are repeatedly changed about in position to ensure perfect regularity of finish in all parts, and to counteract any flaws which may be present in certain plates.

After sorting, and throwing out all defective sheets, separating retree, etc., the reams are counted off according to custom and packed ready for despatch.

It will readily be grasped that the whole procedure of making paper by hand calls for skill and experience of an extremely high order. The slightest drip of water upon the film of pulp as it lays on the mould is sufficient to spoil the sheet, yet, although the vatman's arms are continually being dipped in the liquid, it is only on very rare occasions that the waterleaf is marred. Again, the slightest divergence in the amount of pulp taken up on the mould for each sheet would create a sheet of lighter or heavier substance than that required. Although entirely dependent upon personal skill, it is common practice for ream after ream of light-weight bank post to be turned out with barely perceptible deviation from the standard. This notwithstanding the fact that allowance for subsequent extraction of water, addition of sizing, etc., etc., must be taken into account for each

standard of substance. In the after process of stripping the waterleaf from the felts, the sheets adhere tenaciously to the hairy felt, and in other than skilled hands would be damaged in removal. Here the question of hairs on hand-made paper comes up for discussion. The remarkable fact is that the occurrence of these felt hairs on finished hand-made paper is so rare, considering the tendency of the sheets to adhere to the felts after the tremendous pressure under the hydraulic press. Every precaution is taken in the mills to keep the felts in a constantly clean condition, washing being performed daily, and constant renewals being made. The essential properties of felt render it peculiarly suitable to the functions it is called upon to perform, and no efficient substitute is known.

Account book papers made by hand are, without exception, darker on the right side of the sheet. This is due to the weighty character of the dyes used, which causes them to sink somewhat to the under-side of the sheet while in the form of liquid pulp on the mould. The same thing may happen in the case of machine-made papers, with the difference that, as the wire of the Fourdrinier machine represents the wrong side of the paper, the darkest side of machine-made papers is reverse to that of hand-made.

The deckled or feathered edges which surround the four sides of a hand-made sheet are a characteristic feature. They are created by the slight creeping of the pulp beneath the deckle frame. Thus the term deckled edge.

Mould-made Paper. Mould-made imitations of hand-made paper are produced in several ways, or, rather, by several types of apparatus. These differ essentially from the ordinary paper-making machine, the sheets being formed separately, after the manner of hand-mades. The principal type of machine employs a

cylindrical drum, upon which the size of sheet is arranged by placing bands in position. When the pulp is picked up on the cylinder the bands define the area within which it may lodge, and thus provide the desired deckled edges on all four sides of the sheet.

Another type of machine imitates more closely the apparatus and actions of the vatman and coucher. A movable mould of the required size receives a regulated supply of agitated pulp from an elevated trough through the medium of a series of valves. As the pulp commences to settle down on the mould, a shaking motion serves to felt the fibres and form the sheet. The mould travels and automatically deposits the moist waterleaf (from which the surplus water has been withdrawn by suction during the oscillating shake) on to the couching felts. Succeeding operations are similar in principle to those adopted in the manufacture of hand-made paper.

The similarity in appearance between mould-made and the more expensive hand-made paper rendered necessary a control over the trade descriptions of mould-mades. It is an offence against the law to bestow any title or description inferring or implying " hand-made " to a mould-made production.

In practice it is difficult to differentiate between hand-made and mould-made papers, though it is questionable if the peculiarly characteristic feel of hand-made paper can be imitated perfectly. Transparent spots, caused by sprays of water from the vatman's fingers, are occasional clues to distinguish hand-made. It is held by some experienced judges that mould-made paper is less pliable than hand-made. Where there are the deckled edges and a watermark clearly to be seen, it will almost certainly ensue that there is much sharper definition and clearer transparency in the case of the mould-made paper.

CHAPTER IX

THE VARIOUS FINISHES IMPARTED TO PAPER

PAPER may be finished in various ways, according to the purpose for which it is intended and the character which it is desired to impart. Thus, the following trade terms are employed to designate the different degrees of finish which may be imparted: M.F. (machine finish), Antique (rough finish), S.C. (super-calendered), P.G. (plate-glazed), F.G. (friction-glazed), and Water Finish (usually resorted to for imitation art and similar papers).

Apart from the actual surface influence, finish has an effect in other directions, as opacity, bulk, stretch, etc., according to the particular character of finish imparted. Thus, for example, taking the same body stock and subjecting it to the usual routine of treatment necessary to each finish, a progressive reduction in bulk would ensue, approximating on the average as below—

Antique finish creates		4%	loss in thickness	
Machine	,, ,,	25%	,,	,,
Plate-glazed	,, ,,	37%	,,	,,
Super-calendered	,,	40%	,,	,,

Weight for weight, the stock may remain nearly the same, although it is found as a rule that, in attaining a higher finish, a negligible loss in weight occurs.

Both super-calendering and plate-glazing render a paper more transparent than it otherwise would be, by smoothing out the hollows and projections which, in a dull-finished paper, serve to break up the reflection of light. Up to a certain point, glazing or smoothing

the paper imparts extra strength by compacting the fibres, but excessive pressure, particularly if combined with heat, merely crushes and breaks the fibres, thus causing the paper to become weak and brittle.

Machine finish is the finish imparted to the web during its travel through the machine. Much depends upon the equipment of the machine, for whereas one machine, carrying no calender rolls, or but one set, would produce a rather dead finish, another may be fitted with several stacks of calenders and spraying apparatus which could be made to impart a distinct polish to the paper. As it is understood in the trade, however, machine or mill finish signifies a surface which is but very slightly smoothed.

Antique finish signifies a surface of extreme roughness, to produce which the furnish for the paper is specially selected and treated. The chief characteristics of antique-finished book-paper are bulk, light weight, and roughness of texture. The beating treatment is carried out quickly in order to secure a light and free pulp. Little loading is used, owing to its influence upon the weight, and its tendency to fill up air and fibre spaces. The pressure of the dandy, couch rolls, press rolls, and cylinders is greatly reduced, in order to produce the rough, fibrous surface.

The S.C. finish is imparted by passing the web of paper through a machine known as the super-calender, which consists of a stack of bowls or cylinders, comprising any number from four to upwards of twelve, arranged alternately of polished iron and compressed paper or cotton. Generally, the two centre bowls are of like material for the purpose of running the paper out even on both sides. The machine is driven from a shaft on which is fitted a smaller cogwheel geared into a larger wheel, which drives the

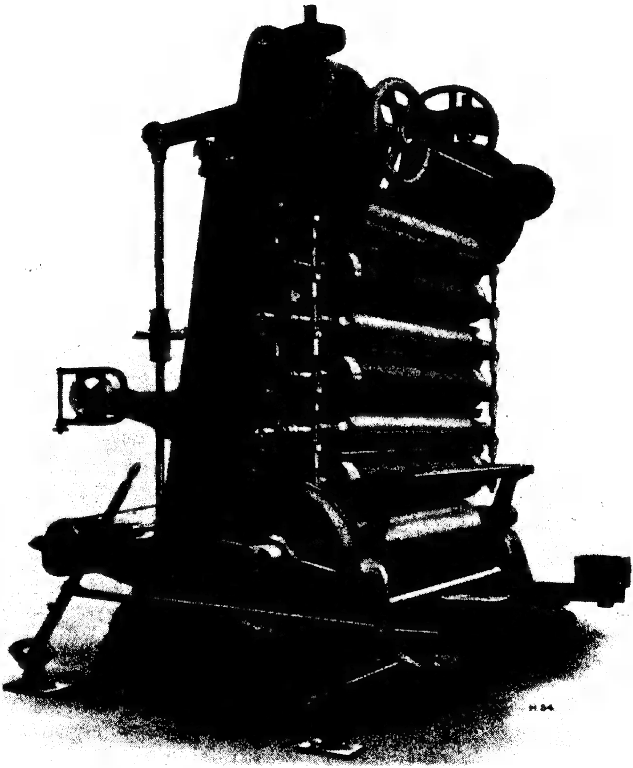

FIG. 23. 7-BOWL SUPER-CALENDER

cylinders. The web of paper is fed into the calender from the reel, and after traversing the cylinders is re-wound on a wooden or iron spindle. For the purpose of keeping the hot iron cylinders out of contact with the paper ones when not in use, and also for increasing or reducing the pressure on the paper, the bowls are adjustable. The paper or cotton bowls are solid, but, for heating purposes, those of iron are hollow and connected up with steam pipes.

To improve the finish obtained in the super-calender, it is usual to give the web of paper a preliminary damping treatment. The principles underlying this are much the same as those appertaining to the ironing of linen in laundry work. In the case of calendering on the machine, a series of fine steam jets or a spraying apparatus may be fixed across the machine before the web reaches the calenders. It is the more approved plan, however, to have the reels damped and allowed to stand before passing forward for the S.C. finish. This permits an even penetration of the moisture and enables maximum effect and durability of finish to be attained.

Several machines to perform the separate damping of the paper are in use. Milne's Patent Damper, which is among the best known, depends upon an air draught for discharging a spray of water on to the web. The latter is unwound from the reel, which works under control in regard to tension, and passes through the machine over leading rollers. Between these is situated the damping device, consisting of a damping roller which revolves in a water duct and deposits its moisture on to an endless wire cloth of fine mesh. As the paper travels along beneath the cloth, the latter receives an air blast, which causes the moisture to deposit on the web in the form of a very fine spray. The amount of water discharged and the speed of the web are adjustable to

meet any requirements. After damping, the web is rewound on a mandrel at the other side and allowed to stand for permeation.

A similar type of machine is also in common use, in which the endless wire cloth and duct roller are substituted by a patent damping box, from which a fine spray is discharged by means of air and water jets, operated by a patent blowing device.

Another machine of recent introduction is Barnes's Spray Damper, which comprises a chamber holding a trough of water, from which a fine spray or mist is discharged on to the travelling web by means of jets of air blown through small nozzles, each containing two orifices. The height of the water in the trough is controlled by a device which regulates the inflow and overflow of water. The orifices in the nozzles are so arranged that while one dips just below the surface of the water, the other is raised slightly above. The air blast through the former raises a fine jet of liquid, while that of the latter breaks up the liquid into spray, which may be regulated to any degree of fineness. The requisite air pressure is provided by an air compressor or blower supplied with the machine.

The S.C. finish is imparted chiefly to printing and book papers which require a finer degree of smoothness than that which may be obtained direct on the paper machine. Such papers closely resemble imitation arts, except that they do not require to carry so much loading. The finish enables the paper to print blacker and more easily, while also enabling better effects to be obtained from line zincos and coarse screen half-tone plates.

Cheap imitation arts and smooth printings are often finished on the paper-making machine, to avoid the expense of the detached super-calendering operation.

In such case, what is termed the water finish is applied. This consists in setting a pair of water ducts in contact with the stack of calenders immediately following the drying cylinders. The heated water is fed to the ducts from an overhead tank by means of pipes. Each duct is fitted with a ductor blade, with adjustable ends to control the water supply. The blades rest against separate calender rolls and transfer the water so that each side of the paper receives a damping. To prevent the extreme edges of the paper being wetted, a blast of air is applied to the margins. Water finish is also applied by spraying the web prior to its entering between the bowls of the super-calender.

Imitation art paper is used by the printer where orders do not permit the cost of real coated art. The purposes for which it is employed are identical with real art, although, where half-tone plates are concerned, the screen or mesh of the pictures is somewhat more open, owing to the interference of the coarser fibrous structure.

Plate-glazed paper for printing purposes is not so much to the fore as it used to be, chiefly because, although the plate finish possesses merits peculiarly its own, the method of imparting it is so slow and costly, compared to other finishes which serve the purpose equally well. At the present time, plate-glazing is chiefly confined to hand-mades, account-book papers, superfine lithos. and glazed book printings. The method employed in imparting it was sufficiently described in Chapter VIII, under the heading of Hand-made Paper. The chief advantages are that all the fibres are affected by the process, and the finish is as permanent as any that can be obtained. The colour of the paper remains uninjured, a fact which does not apply with equal force to all other finishes. Streakiness and flaws in the finish, which are often associated with the polishes

obtained by damp, heat, and friction, are practically impossible when plate-glazing is the medium employed.

Friction glazing is a much cheaper and more artificial

FIG. 24. 3-BOWL HEAVY FRICTION-GLAZING MACHINE

finish than either S.C. or P.G., although, for certain classes of paper, it produces a desired effect which could not be attained by other means. Such papers include flints, box enamels, burnished wrappings, tin foils,

novelty cover papers, and certain soft sized printings on which a higher finish than usual is desired. In all these varieties, the finish is required on one side of the paper only.

The method of burnishing the web is to pass it through beeswaxed bowls, or cylinders, of different diameter, revolving at different speeds. The larger roll is usually composed of compressed paper, while the smaller one (occasionally two) is of polished iron or steel. Instead of beeswax, paraffin wax is sometimes applied to the cylinders, while some paper-makers employ a composition of their own make which enables a brilliant burnish to be obtained. Great care is necessary to keep the cylinders in good condition, for the slightest defect is exaggerated in the finish on the paper, owing to the scratching action which arises. Grit or flaws on the cylinders scratch and scrape the surface of the stock, leaving very visible traces of the defect. Neglect to apply the wax properly allows the composition to dry on the bowls, the resultant hardness causing the paper to crack.

The paper, after being finished and allowed to stand, is passed forward to the slitting or cutting department, where it is reduced to specified widths of reel, or cut to standard size sheets ready for counting off and packing in reams. News-print and other types of paper for use on rotary machines, etc., are usually sent out in the reel.

Cutting in reels of specified width may be performed direct on the paper-machine, or slitting machines which are built to carry as many as eight or ten reels for simultaneous slitting may be employed for separate action. The essential part of these machines is a pair of shafts carrying a series of pairs of circular ripping knives, the upper disc being fitted with a hollow-ground projecting flange, which acts with a scissor-like motion

against the sharp edge of the lower disc. The cutters are maintained in keen contact by means of a spring attachment.

The revolving cutter, used for cutting the sheets into single sheets, works on a similar principle to the foregoing for the longitudinal slit, but, to perform the cross cut, a revolving drum, fitted with a knife blade, is situated after the slitters. As the knife descends on to the sheet it comes in close contact with a stationary knife. To obtain the necessary shearing action, the drum knife is fixed at a slightly oblique angle. Thus a clear, unburred edge is imparted to the single sheets. The sheets, as they are cut, fall on to a travelling felt, from which they are collected and passed forward for sorting, counting, etc.

To regulate the size of sheets to be cut, the leading rolls and cutting drum are adjustable to different speeds by means of expanding and change pulleys. Slight adjustments in size may be made while the machine is in motion.

Variations and improvements are effected, and different types of machinery devised, to meet the requirements of such special classes of paper as tissues, highly glazed papers, angular envelope papers, etc. A special type of machine is also made which simultaneously cuts two different lengths, of different widths, from the same web.

For watermarked papers, in which the device must fall to register in the centre of every sheet or part of the sheet, a more accurate sort of machine, known as the Single Sheet English Drum-cutter, is usually employed. In this machine, the web of paper is fed through a pair of rolls, under a tension roller, and thence round a large oscillating wooden drum, against which it is held taut by a clamping device. The travel of the

drum controls the size of the sheet to be cut, and the former is regulated by adjusting a crank arm, which is connected up to the driving wheel. After carrying the web forward a sufficient distance, the drum returns to its former position, the paper meantime being held securely clamped so that it cannot move out of position. Cutting is performed by a pair of knives, which take the paper as it comes from the drum, one of the knives being fixed and the other movable.

The Continental method of cutting watermarked sheets is to employ a machine which works with a reciprocating clamp motion. The web is led from the reel and through the slitters on to a travelling felt fitted over a flat bed. A reciprocating clamp, adjusted to the size of sheet required, engages the paper and carries it forward to the cross-cutting knives, which work with a guillotine motion. The clamp then lifts free of the web and journeys back to clamp the paper at regulated distance and repeat the former movement.

An English machine is now made (the Vickery Cutter) which combines the advantages of the English Drum Cutter with the Continental (Verney) clamp type. In this machine, two reels may be simultaneously cut, which economizes in time and, by the mode of adjusting the cut, eliminates the waste of time on setting for square, or trueing up. The web is continually advancing forward, instead of standing after every cut, as in the other types of machine, while, as a means of ensuring absolute accuracy in the size of the cut sheets, the measuring device and the cross-cut knife are positively geared together.

Another type of web-cutting machine that may be briefly described is the Vertical Drum Slitter and Reeler, which comprises a vertical frame and the necessary driving wheels. The reel is carried at the bottom

and is unwound on to a spindle situated directly above, against which react a series of circular slitters arranged on a shaft. The extreme edges of the paper are trimmed off before the web is taken up on the spindle. As the web is slit and wound, the constantly increasing diameter is accommodated by automatic gearing which raises the slitters, while, to ensure a clean cut, the slitters are separately driven at an increased speed.

A machine very similar to the foregoing is built on the horizontal plan, the main feature of difference consisting in the arrangement of the slitters.

After slitting, or cutting into sheets, these are gathered and conveyed to the sorters, who overlook and throw out all defective sheets, sorting them into perfect, retree, outsides, or brokes, etc. Following upon this the sheets are counted off into quires and reams which are then packed and labelled ready for despatch.

Certain new types of finish have been introduced with the development of cover papers, fashionable stationery, fancy box papers, and novelty wrapping papers. Mainly, these finishes are embossings performed either on the reel or on the sheets after the paper-maker has done with his part of the making. They comprise a tremendously wide range of patterns, from the ordinary hammer or repoussé finish familiar in cover papers and bond papers, to the fashionable cambric finish of typewriting or domestic stationery, and on to the imitation leather, fabric, and speciality embossings now in demand for cover papers, end-linings, fancy box coverings, and pattern-card making. Sometimes these finishes are imparted to illustrated sheets after printing, in the same way that canvas grainings and brush markings are added to reproductions of paintings in order to heighten the effect of imitation.

CHAPTER X

COATED PAPER

Coated paper is the term applied to that class of stock[1] which consists of an ordinary body paper to which has been applied a surface film of enamel, usually for the purpose of securing an artistic effect or imparting a special character for printing. Such papers may be enamelled, or coated, on one or both sides, and may be white or stained, while they may also be finished matt, smooth, or glossy.

Chief among the varieties which come under the heading of coated are: photographic paper, chromo and bright enamel for lithographic colour printing, offset chromo for offset colour printing, art paper for letterpress three-colour and half-tone work, and surface coloured flints and enamels for the box-making and fancy stationery trades.

In the case of chromo and bright enamel papers, the type of surface, with the natural affinity of the clay towards dye and pigmentary colours, helps the attainment of pure and even tones, while also lessening the troubles of stretch and impression during printing. Coated paper is even more necessary in letterpress printing where the forme contains half-tone plates. In such cases, the screen or grain of the plates commonly employed is about 133 to the linear inch, and such a mass of fine points as this represents requires the smoothest surface possible for effective reproduction. The ordinary fibrous surface of even the most firmly crushed or rolled stock is quite unfitted to reproduce correctly the delicate structure of the process plate. To give the desired

[1] "Stock" is a trade term now popularly used to designate paper of any sort.

effect in printing, every projecting point of the plate should be perfectly rendered. This is impossible by ordinary methods except upon a perfectly smooth, flat surface; and even here much depends upon other factors, principally the ink.

Notwithstanding the many well-known defects of art paper, the half-tone plate has become so indispensable a factor in modern printing that coated paper is an absolute necessity where good work is desired. The best class super-calendered or imitation art papers do not yield results in half-tone printing that can compare against those produced on coated art.

The mode of manufacture in common use for the production of art and chromo papers consists in first making the full width web of body paper, which is afterwards cut to smaller reels, matured, and finally coated on a special machine. The best class of body stock is prepared from Spanish esparto, chemical soda wood, or a combination of the two. The fibre is sharply beaten to avoid greasiness or wetness, thus minimizing stretch or expansion in the ultimate paper, and at the same time enabling the coating solution to spread evenly and take a secure hold. Strength of texture is not of great importance, although it is necessary to avoid undue weakness or brittleness. Resin size is added to the pulp, which helps to bind the fibre, but principally aids the paper to present a good holding surface to the coating solution. The latter requires to adhere as firmly as ever possible in view of the pull exerted at the moment of producing the printed impression. Body stock which is too absorbent allows the glue to sink in, leaving a clay surface of weak and powdery character.

While in the beating engine, the pulp is loaded and slightly coloured as for ordinary printing, but the

surface is left matt or unfinished to help further in holding the coating. Too high a finish results in streaky coating and causes frequent picking or plucking to occur during printing.

After manufacture, the web is slit to the widths of reel required, allowing a margin at each edge for trimming after coating, due to the thickening which inevitably occurs at the extremities. Following an ample time allowance in which to thoroughly mature, the reels are passed to the coating department for application of the enamel, etc. The coating machine comprises a cylinder of 3 to 4 ft. diameter, against which is situated a duct or trough holding the heated solution for coating. The latter is applied to the paper and regulated by a travelling felt, while the weight or thickness of coating and the levelling operation is controlled and performed as the web travels on the cylinder by a series of oscillating and stationary brushes, geared up in contact with the surface of the drum. The bristles of the brushes are of varying character, in order to produce a uniform and level surface throughout the area of the web.

The coating solution is composed of clay and glue, the former constituting the surfacing material, and the latter acting as the binding medium. The quality of the clay is the main factor in producing a uniform surface, free from irregularities. Three forms of mineral may be used, according to the quality of coated paper being made. The cheapest and most largely used is china clay or kaolin, while for better class stock calcium or barium sulphate may be used. China clay often contains gritty matter and other impurities which reveal themselves on the surface of the finished paper. China clay is composed of larger and coarser particles than calcium or barium sulphate, and, especially in the cheaper grades, contains an amount of sand and grit.

Calcium sulphate, known also as satin white, or pearl hardening, is an exceedingly fine precipitate, beautifully white and capable of forming a perfectly compact surface. Barium sulphate (blanc fixe or heavy spar) is prepared artificially, and is of much the same nature as satin white, being quite free from foreign particles which would detract from the evenness of the coating.

In preparing the coating paste, it is necessary to strike correctly the proportions of clay and glue, or glue substitute. An excess of clay over glue would cause a weak coating, unable to resist the pull exerted by the ink and varnish at the moment of leaving the impression during printing. The troubles which arise in this way are known to printers as plucking, peeling, picking, or lifting. On the other hand, excess of glue creates hardness of surface and a tendency toward greasiness, which retards the drying of printing ink and causes patchy or piebald impressions to be made. Unless the glue or gelatine is quite fresh and pure when used, it will impart to the paper an offensive odour. The proportions of glue and clay in the coating solution approximate to 18 to 25 lb. of the former to 100 lb. of the latter.

Casein is now largely used as a substitute for glue. The advantages claimed are : freedom from odour ; the preparation of a surface which, though quite insoluble, is receptive toward printing inks ; and cheapness and ease of preparation. To set against this, however, there is a danger of reduced colour value and danger of chemical reaction due to impurity or residue in casein which has been carelessly manufactured.

Starch has also been suggested and used as a substitute for glue, the starch being boiled to a thin, clear solution and an amount of alum added. The clay is separately prepared by mixing with silicate of soda (water-glass) and water, this mixture being afterwards

added to the starch and alum solution. Certain advantages are claimed for this process of coating, but hitherto the use of the patent has been practically confined to Germany and America. Starch-coated art paper is essentially a cheaper substitute for clay-coated paper, and is only suitable for low-grade printing.

Reverting to the coating of the body stock, the web, after being coated and levelled, requires drying. For this, the travelling web is carried upwards on rods, which are lifted by chains and conveyed along an overhead track. The rod and chain arrangement is controlled so that the web of paper is raised at intervals, allowing it to hang in a continuous series of festoons. The festoons are carried slowly forward throughout the length of a long drying chamber, which is heated on a graduated plan, rising to about 90° F. at the end of the forward journey. The rods then make a semicircular turn and convey the paper back to be reeled in a dry state parallel with the starting-point. In this condition the web is coated one side only, and, if a two-sided art is required, the operation must be repeated for the other side. Where colouring or staining is to be performed, the dye-stuff is mixed in with the coating solution. The coated paper still requires finishing, which is performed by one or other of the methods described in the chapter on Finishing. A slight calendering imparts the characteristic chromo finish, while art papers require running through a large stack of calenders. Flint papers and box enamels are burnished in the friction glazer, while bright enamels for lithographic printing, and the more highly polished art papers are by the most recent process treated in a machine of which the main feature is a brush cylinder revolving against the coated web at a tremendously high rate of speed.

CHAPTER XI

TESTING

TESTING, as applied to the art of paper-making, may be considered under three heads—

1. Tests of raw materials.
2. Tests of manufactured paper.
3. Practical judging of value.

The accomplishment of tests under Class 1 properly belongs to the mill chemist; those under Class 2 being performed by the mill chemist and also the paper user; while the rougher sort of testing or judging is daily carried out among printers, paper agents, and paper users. For the accurate performance of tests of the more technical nature, a proper scientific training and comprehensive equipment is essential.

Microscopic investigation, which comes into use in Classes 1 and 2, has already been described (Chapter III) as applied to fibres, and therefore does not call for further discussion at this stage.

Tests of Materials used in Paper-making.

WATER. Water may contain organic or inorganic impurity in sufficient quantity to be detrimental to the production of good paper. The vast volume of water employed in the manufacture of paper makes it necessary to have the supply as pure as possible, even though special plant or treatment be requisite, as for filtration, purification, or softening, etc.

Impurity in water may consist of either suspended or dissolved matter. The former is detected by drawing off a sample of the water into a glass cylinder and allowing it to stand. Organic impurity settles much more slowly than mineral or inorganic impurity.

Investigation of the nature and amount of the sediment is effected by filtration, and drying, weighing, and ignition, the loss in weight indicating the proportion of organic matter. The inorganic residue is then tested by ordinary methods of chemical analysis.

The water supply in some districts is what is termed "hard," due to the presence of dissolved inorganic salts. Hardness may be of two kinds, known respectively as temporary and permanent. Temporary hardness is due to the presence of bicarbonate of lime or magnesium, which, on boiling, decomposes, leaving a crust or deposit of carbonate on the sides of the vessel. Permanent hardness is caused by the presence of sulphates and chlorides of calcium and magnesium, which do not decompose when the water is boiled. The amount of a standard soap required to overcome the hardness of the water and produce a lather indicates the total hardness of the water. For correct results, the operation is conducted on a standardized basis.

Magnesium in water is detected by boiling and adding ammonium carbonate and sodium phosphate, which, in the presence of magnesium, forms a white precipitate.

Dissolved sulphates yield a white precipitate of barium sulphate (insoluble in nitric acid) when a drop of barium chloride is added.

Carbonic acid gas in water is determined by the white carbonate of lime which is formed when lime-water is added.

Soluble lime impurities give a milky precipitate in the presence of a crystal of oxalic acid.

Sulphur in water is identified by stoppering and allowing to stand, a tube of the water containing one globule of mercury. The latter combines with the sulphur to form mercuric sulphide, a dark precipitate which collects on the globule.

Iron in water is proved by the grey or black colouration produced when a few drops of tincture of nutgall are added to the sample. Quantitative analysis is performed by evaporation, acidifying, and titrating with a standardized solution of ferric iron, in Nessler tubes. The reaction forms prussian blue with the characteristic coloration.

COAL. Coal is examined for moisture, percentage ash, and calorific value. A sample representative of the whole bulk is obtained and crushed to powder. To determine the amount of moisture present, a known weight is dried in a steam-jacketed oven at about 100° C., until the weight becomes constant. The loss in weight represents moisture, and is calculated as a percentage factor.

The amount of ash in coal is determined by gently incinerating the powder sample, being careful to avoid fusing the ash. The weight of ash remaining at the end of the action is calculated out as a percentage on the original sample. The colour and behaviour of the ash should be carefully observed. If black particles still remain, the incineration is incomplete, or fusing has taken place. If the ash appears of a red or brown colour, it may be taken as indicative of the presence of sulphur, probably in the form of pyrites.

Calorific value is determined by using the calorimeter, an apparatus consisting of a chamber surrounded by a jacket containing a known volume of water. The sample of coal is burnt in the chamber, by electric ignition or other means, and the heat generated is absorbed by the water. A thermometer attachment indicates the degrees of heat, and the result is expressed in terms of B.Th.U. (British Thermal Units), the unit representing the amount of heat required to raise 1 lb. of water through 1° F.

The Continental, and more scientific record of heat value is the calorie, 1 calorie representing the amount of heat required to raise 1 gramme of water through 1° C.

MOISTURE IN WOOD-PULP. The testing of wood-pulp for moisture content is an important feature in the routine of the paper-mill chemist.

Wood-pulp, as it arrives in England, may be listed as moist (i.e. 50 per cent wet) or air dry, the English standard for the latter allowing 10 per cent moisture. In other words, 100 parts of air-dry pulp contain 90 parts of bone-dry material and 10 parts of moisture.

The test for moisture is carried out by taking representative samples of the consignment from near the top, centre, and bottom, and making up to known weight. The pulp is then dried at constant temperature of 100 to 105° C., in a special oven fitted with a holding basket, thermometer, and regulating and balance attachments. From the weighing balance, the progress of the drying is ascertained, and when constant, the figures are read off and calculated out in terms of percentage loss on the original weight of wood-pulp. The result is expressed in terms of absolutely dry pulp, percentage of moisture, percentage of air-dry or moist pulp, and percentage of excess moisture over stipulation.

EVALUATION OF WOOD-PULP. Standardized methods have recently been worked out and adopted by the British Paper Industry for the evaluation of wood-pulp, chemical and mechanical. Standard equipment, comprising disintegrator, sheet-making machine, pump and press, and accessories have been devised; and for freeness testing the Canadian Standard Freeness Tester has been adopted. The procedure of wood-pulp testing may be summarized as follows: A representative

selection of samples of not less than 100 grammes of dry fibre is made from different parts of the pulp consignment. The buyer and seller each retain similar samples for reference. The testing sample is reduced to small pieces and 24 grammes withdrawn, wetted, and allowed to stand, then made up to 2,000 c.c. with water, disintegrated in the special apparatus, and diluted up to 8 litres. Next, under specified conditions, sheets of pulp of definite substance are formed in the sheet-making machine. Surplus moisture is removed by a couching device, and the sheets are lifted from the wire. Seven sheets are made, interspersed with filler, blotter and metal plate between each. The pile is subjected to set pressure under specified conditions, reversed in order and pressed again. After removing the pile and separating, the metal plates with test sheets attached are fitted into a set of drying rings and dried flat with an M.G. finish (rough one side and smooth the other) under pressure. Next they are placed in an atmosphere of 65 per cent relative humidity and 70° F. for at least twelve hours, allowing circulation of air for at least an hour. The sheets are tested under similar air conditions. One sheet is examined for surface character, opacity, and general appearance. The remaining sheets are tested for thickness, strength, stretch, tearing strain, bursting resistance, and the findings are expressed according to the official recommendations. In the case of mechanical wood-pulp, freeness is determined by the Canadian Standard Freeness Tester, five tests being made under corresponding temperatures and according to the standard conditions.

Bleaching Powder. Bleach is tested for a determination of the available chlorine present in the sample by titration with a standardized solution of arsenious acid. To perform the test, a decinormal solution of

the acid is obtained or prepared by the usual method. The sample of bleaching powder is weighed out and reduced to a thin paste with water, then made up to 500 c.c. in a flask, from which 50 c.c. are taken for titration with the arsenious acid solution. The bleach liquor under test is constantly stirred as the drops fall from the burette, and from time to time the state of the liquor is tested on a prepared solution of potassium iodide and starch (usually in the form of starch papers). So long as chlorine remains in the bleach solution a blue coloration results: the moment that this stain fails to appear marks the end of the reaction. The number of c.c. of decinormal arsenious acid required to complete the reaction is read off from the burette and calculated out in terms of available chlorine, each c.c. of arsenious acid being equal to ·00355 grammes of chlorine.

CAUSTIC SODA is examined for real soda value by dissolving up a given weight in boiling water, colouring with litmus or methyl orange indicator, and titrating with a standardized (normal) solution of sulphuric acid. The coloration of the solution changes to red the moment the acid neutralizes the alkaline character. From the reading of the burette the soda value of the original sample may be calculated in terms of sodium oxide; 1 c.c. of normal acid equalling 0·031 grammes Na_2O.

CLAY LOADINGS, or Mineral Fillers, are usually tested to determine moisture, impurity, bulking capacity, and colour. Moisture is ascertained by drying a sample of known weight at constant temperature in a drying oven, until all the moisture is driven off and the weight remains constant. The loss in weight, calculated out as a percentage of the original sample, represents water. The clay, however, retains its chemically

combined water, which is so bound up that only prolonged incineration would remove it, a process unnecessary when the moisture test is undertaken for commercial purpose.

China clay often contains traces of iron compounds, which are injurious to colour. The test for iron in clay is performed by extraction with hydrochloric acid and application of the potassium ferrocyanide solution, which, in the presence of iron compounds, will form the characteristic prussian blue coloration. The experiment should be conducted with the aid of Nessler tubes.

Grit is a characteristic impurity of cheap clays, and may be discovered by the feel of the sample, or by thoroughly mixing a portion with water and sieving through a fine screen of about 200 mesh. The grit and larger particles of mineral remain on the screen. After washing and rubbing, to remove as much as possible, the residue is dried, removed from the screen, weighed, and calculated as a percentage.

The voluminous character of the clay, which is an important feature, considering the necessary function of the material, may also be determined by an examination of the bulk which the particles form as they settle from suspension in water.

Colour is determined by compounding into a paste and comparing with known standards of colour in the form of porcelain slabs or similar reliable composition. Alternatively, the colour of a sample may be gauged by mixing up solutions of the clay to be tested and a clay of known reliable brand and colour, and making comparative examination for colour value through the medium of Nessler tubes.

Satin white is a loader artificially prepared from lime and alum, the chief dangers from which are the

presence of traces of free lime or acid. The application of litmus indicator and the effect upon coloration will afford a guide as to the nature of the material in solution. Free aluminium sulphate may be tested for on a portion of the mineral held in suspension in water. The mixture should be shaken and allowed to stand, then filtered, and a few drops of ammonia added, following which the contents of the tube are boiled. If free soluble aluminium sulphate is present, a white flocculent precipitate will develop.

Gelatine or glue is examined for colour, odour, moisture, ash, absorptive power, gelatinizing power and viscosity, and acidity. The best glue should be transparent, pale, and free from objectionable smell. The amount of moisture is determined by methods previously named. Ordinary glue may contain 10 to 18 per cent of moisture. Ash content (due to minerals) is found by complete incineration and weighing. Absorptive power is ascertained by immersing a known weight (10 grammes) of glue in 200 c.c. of cold water for twenty-four hours, draining off surplus water and weighing the swollen product. Gelatinization power is determined by the weight required to break through a jellified 10 per cent solution of the glue. For the viscosity test, 50 c.c. of a 1 per cent solution of the glue is entered into a burette at standard temperature. The time required to run off the whole volume, compared against the time required to run a similar volume of distilled water, affords a practical measure of the viscosity of the sample. The better the glue, the longer time will be taken to run off the 50 c.c. Acidity is quantitatively determined by performing a titration of a 10 per cent solution against a standard solution of alkali in the presence of phenol phthalein as indicator.

Testing Paper. The testing of paper divides itself into three sections, viz.—

1. Microscopic examination.
2. Physical testing.
3. Chemical analysis.

Section 1 deals with fibres, the structure of the sheet, character of loadings used, nature of impurities, etc.

Section 2 concerns the properties of the paper in regard to strength, folding or wearing capacity, colour, opacity, weight, thickness, etc.

Section 3 takes in hand the determination of sizing agents, ash content and character, detection of impurities, residues, etc.

The microscopic characteristics of mineral loadings afford an indication of their original source. Examination of disintegrated paper or of the ash, after incineration of the paper, may be made; or, in the case of coated papers, a sufficient amount of the substance may be detached by scraping the surface of the sample. China clay (kaolin) is characterized by small oval and rounded particles, fairly uniform in size in good qualities. Calcium sulphate (pearl hardening, satin white, etc.) comprises crystals of irregular shape, usually in the form of minute prisms and needles. Barium sulphate (barytes, heavy spar, etc.) may be recognized by the more squat crystals of diamond and wedge shape.

Starch, under the microscope, appears in the form of granules or globules, which vary in size and shape, according to their source of origin. Potato and wheat starch show much larger granules than rice or maize.

PHYSICAL TESTS. The strength of paper may be tested by ascertaining the bursting or breaking strain of a sample, for which purpose a large variety of machines are made. Those which undertake the bursting test include the Mullen, Ashcroft, Edwards, Rehse, Eddy,

etc., all of which embody a somewhat similar principle. In these machines, the paper is clamped over a cylinder or against a rubber diaphragm, against which pressure is brought to bear by turning a handle wheel, whereby a special fluid is forced in contact, thus reacting against the circular area of the sample exposed to the strain. At the same time, the fluid acts directly upon a carefully calibrated pressure gauge, which records on a dial the pressure in lbs. per square inch. At the moment of bursting, the indicator remains stationary and, after taking the data, can be released to fall to zero, the fluid returning to its former level.

The Dalen-Schopper machine is a recent addition to this class, and marks an advance in the direction of indicating stretch up to the point of bursting. A small circle of the paper is subjected to the force of compressed air, and the amount of air required to effect a burst is measured off and indicated in lbs. per square inch.

The Edwards's Improved Hydrostatic Tester makes use of a washer of special composition, unaffected by oil or other fluid, and embodies the principle of hydraulics, thereby rendering unnecessary the use of springs, rubber valves, etc., which are liable to atmospheric effect and variation.

On any instrument an average of five or ten readings should be taken as the working standard.

The breaking or tearing strength of paper is ascertained on a strip testing machine of the Marshall or Schopper type, which records the tension (in lbs. or kilogrammes) required to break a standard size strip of paper.

Marshall's instrument is fitted with a pair of clamps, D, which securely hold the strip of paper cut to standard size by a special device, F.G. By turning a hand wheel, B, the clamps are drawn apart and tension is

brought to bear through the strip of paper upon liquid contained in the cylinder A. Under the same influence, the tension put upon the paper is indicated upon a dial, C, which gives the reading in lbs., required to execute a

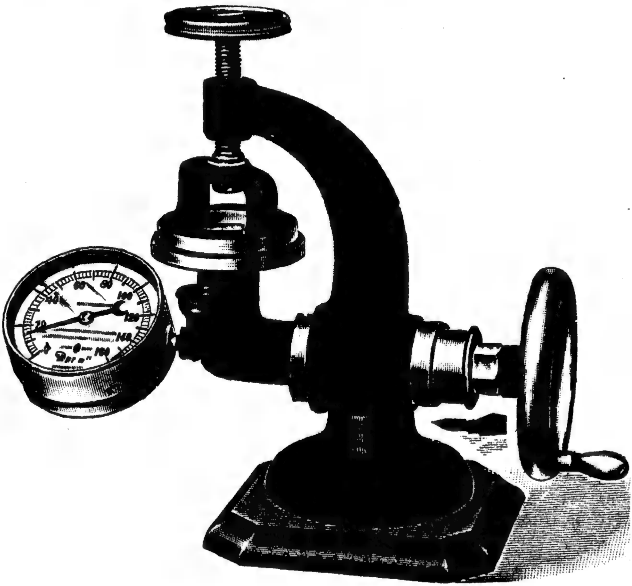

FIG. 25. EDWARDS'S HYDROSTATIC PAPER TESTER

direct break. The stretch or elongation which the paper undergoes up to the moment of breaking is also registered (E) for conversion into a percentage factor calculated on the exposed length of strip. To return the clamp to normal and return the indicator the screw wheel is turned the reverse way.

Schopper's apparatus gives the same data by a somewhat different method. The instrument resembles a

quadrant in shape, fitted with a swinging pendulum actuated by a hydraulic piston rod worked by hand or power. The strip of paper, cut to standard size, is held in a vertical position between a pair of self-adjustable clamps. In motion, the hydraulic piston exerts the necessary pull on the strip of paper and causes the

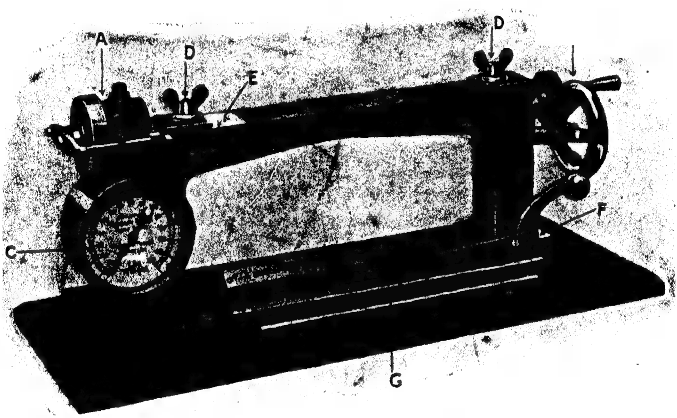

FIG. 26. MARSHALL'S PAPER-TESTING MACHINE

pendulum to travel along a curved scale, upon which is recorded the pressure. A smaller scale, situated above, records the percentage elongation undergone by the strip of paper up to breaking point. By an ingenious tooth rack and series ratchet device, the levers and indicators are arrested at the precise moment the break occurs.

With both the Marshall and the Schopper machines, it is essential to test the paper in both cross and machine directions, while, for the sake of accuracy, no less than five, but preferably ten, tests each way should be

undertaken, the mean average being accepted as the result.

Folding strength is determined on a machine of the Schopper, Leunig, Kirschner, or Pfuhl type. The Leunig machine takes a strip of standard dimensions, which passes through a slit plate and is held taut by clips controlled by springs. By turning a handle wheel attached to a crank arm, the slit metal plate through which the paper sits is rapidly reciprocated, thus executing the action of folding the strip. The wheel shaft runs in geared contact with a horizontal indicating dial registering up to tens of thousands. At the moment of breaking, the dial is thrown out of gear, and the indicator remains stationary.

The probable elongation or contraction of a given sheet of printing paper is tested by hanging a standard strip clipped in an apparatus which holds the strip exposed to damp and connected with a pointer which indicates movement along a measured arc. The approved testing equipment is by Schopper, of Leipzig.

Thickness of paper is gauged by use of the paper micrometer which, by means of a spring, will indicate to 1000ths of a mm., or the ten-thousandth part of an inch. The instrument is fitted with a figured dial and indicating finger.

Opacity may be quantitatively measured by means of instruments, such as Dr. Klem's Diaphanometer or Clayton Beadle's device, in both of which the principle employed is that of inserting a sufficient number of sheets to blank out an illumination. The number of sheets and their volume is the measure of transparency or opacity.

Finish, surface gloss, or the degree of smoothness of paper can be determined, measured, and indicated in comparative numerical terms by the Glarimeter, to be afterwards expressed on a percentage basis. In the

instrument a beam of light is directed on to the enclosed sample of paper at a tangent, and is passed through a slit to divide into two polarized constituents. These beams pass through a lens to a prism, which on rotation establishes a brightness comparison to be read off on a scale.

The weight of paper per sheet, or per ream of 480, 500, and 516 sheets, may be found from a full sheet or small piece of standard size by means of the Quadrant Paper Scale or the Demy paper balance.

The ink-resisting property of paper is ascertained in a roughly practical way by drawing coarse lines in ink of known make with a broad steel nib or quill pen. The amount of spreading and degree of penetration mark the measure of ink resistance.

A more scientific method is to employ the Schluttig and Neumann solutions, the composition of which is—

A Solution.

100	c.c.	Water (distilled)
2·9	gms.	Ferric chloride
1	,,	Iron
1	,,	Gum arabic
0·2	,,	Phenol

B Solution

1% solution of Tannic Acid containing 2% of Phenol.

The sheet to be tested is arranged on an apparatus the shape of a roof, held in a tray, with sides sloping at 60°. A few drops of A solution are trickled down in three places on the sample, simultaneously for preference. After standing about fifteen minutes, the sheet is turned over and three streams of B solution trickled down, to run at right angles to those on the reverse side. The time required for the tannic solution to penetrate and cause a black stain through contact with the iron salt is indicative of the ink-resisting value of the sample. For comparison, a table of times should be

compiled from tests on various papers of standard make.

The absorbency of blottings is tested by suspending standard size strips from an apparatus which allows the ends of the strips to be dipped simultaneously to a given depth in water or ink. The quality of the paper for its purpose is judged by the height to which the liquid is absorbed within five minutes.

CHEMICAL TESTS. The moisture contained in paper, which in ordinary circumstances averages about 7 per cent, is determined by the methods already given for moisture in materials.

The class of sizing employed in the making of the paper is identified by the following tests, most of which may be performed with test-tube apparatus.

Paper which has been sized with resin will give a white precipitate if distilled water is added to the cold filtrate obtained after warming the paper in alcohol containing one or two drops of acetic acid.

Alternatively, if the sample is boiled in glaciol acetic acid, the addition of a little water will cause turbidity in the presence of resin sizing.

Under the foregoing tests the solution from tub-sized paper would remain clear.

To prove the presence of engine (or resin) size without destroying the paper, apply two or three drops of Absolute Ether to the surface of the sample. The effect of the ether is to dissolve the resin, driving it to the edge of the ring where it remains after the ether evaporates.

To identify tub-sized papers, the sample is boiled in distilled water and the filtrate allowed to cool. A few drops of cold 1 per cent. tannic acid solution are then added, and if gelatine or tub-size has been employed, a flocculent creamy precipitate will be produced. Many papers contain both resin and tub-size; it is, therefore,

advisable to conduct both the glacial acetic and tannic acid tests.

Millon's reagent may also be used in testing for tub-size. The solution is made by adding together equal parts of metallic mercury and fuming nitric acid, the operation, owing to fumes, being performed in open air. Allow to stand for twelve hours, then add an equal bulk of distilled water. To test, the paper is torn to fragments, placed in a watch glass, covered with solution, and then warmed gently. If tub-sized, a pink coloration will appear, which, however, requires careful observation owing to its fugitive nature.

The quantitative test for resin sizing is carried out in a Soxhlet apparatus; while for gelatine sizing the estimation is made under the Kjeldahl method.

Casein as a sizing agent may be detected by means of Millon's reagent and distinguished from gelatine by the application of the tannic acid test, with which casein gives no reaction. To test coated papers for the presence of casein, dissolve off the coating in sodium carbonate, or caustic soda, and neutralize the extract by application of weak acetic acid, which precipitates the casein. Wash well with water and alcohol, dry, and then warm the casein with a mixture of two volumes of glaciol acetic acid and one volume of condensed sulphuric acid, when a characteristic red violet coloration will be produced.

Starch in paper may be identified by treating the sample with a weak, amber-coloured solution of iodine in potassium iodide, which, in the presence of starch, develops a blue coloration. Most high-grade papers, made from old linen rags, contain traces of the starch originally employed in dressing the fabric. The strength of the blue stain gives a rough guide to the amount of starch contained in the paper.

The amount of mineral loading added to paper is determined by completely incinerating a dried sample of known weight in a crucible over a bunsen flame. Care is needed to burn off all the carbon completely, leaving the ash free from black particles. The weight of the ash is found and calculated out as a percentage on the weight of the original bone-dry sample of paper. The colour of the ash may afford some clue to the nature of the clay or class of colouring material used in making the paper.

Red ash denotes iron in the clay or the use of ochre pigments in dyeing the pulp.

Blue ash denotes that ultramarine or smalts has been used in dyeing the pulp.

Yellow ash denotes that chrome yellow has been used in dyeing the pulp.

The qualitative and quantitative tests for loading materials used are most intricate and beyond the scope of this volume.

Practical Judging of Paper. In a purely practical way, the quality of paper may be judged as follows: Quality is inseparably bound up with price, and efficiency is met if the paper serves the particular purpose for which it has been made. Some papers call for strength, while colour is of no account. Other papers must bear a certain type of finish and colour, while strength is not important. The function of any paper must carefully be held for consideration before an opinion can be passed on its value.

Generally speaking, strength is denoted by the way in which the paper tears in both cross and length directions. An imitation of the bursting strain, useful on wrapping-papers, is to force the finger through the paper from the under-surface. Rubbing between the fingers and thumbs, or crumpling severely, will show, by the

punctures produced, the extent to which the paper may withstand wear and tear. The rattle of a paper is a guide to strength and efficiency of sizing. Good, strongly-sized paper has a tin-like crackle and snap. When wetted with the tongue, weakly-sized paper becomes limp and transparent through penetration. The look-through of paper denotes the cleanliness and freedom from specks or clots of fibre. A cloudy yet clean appearance is often an indication of tub-sizing, which may be checked by the feel or rattle. To observe the finish correctly, hold the sample level with the eyes, making observation of both sides of the sheet for even-sidedness. Colour value may be gauged by comparison with a known reliable make. Weight is judged by the compactness and bulking capacity of the paper.

To determine the machine cross-way and length direction of a paper, examine carefully the wove wire marks in the look-through. Each minute mark is of an elongated diamond shape, the longitudinal way of which denotes the lengthway, or machine direction of the sheet. As a confirmation test, cut a small disc of paper, marking the position from which it is cut; damp one side and allow it to curl tube shape. The way through the tube represents the length or machine direction of the sheet.

Paper stretches more in the cross-way of the sheet, therefore, for colour printing and other purposes, the direction of the sheet must be known.

To obtain an idea of the resistance of a paper to stretch, cut strips each way of the sheet to standard measure, damp thoroughly, and lay on glass. Before the drying process shows an indication of commencement, take the dimensions of the expanded strips and work out the finding as a percentage.

Acid traces in paper may be proved by applying a

drop of Congo Red solution, which, in presence of acid residue, will turn blue. Opacity is judged by the number of sheets required to obliterate a standard line of heavy black type.

To distinguish real coated from imitation art paper, rub with a silver coin. If coated, a black mark will be produced on the surface. To judge the quality of the coating damp the ball of the thumb and press heavily. A good coating will remain unmoved, but, if weakly held, a portion of the clay will come away with the thumb.

Kraft brown paper may be detected from common imitation by burning a sample. Real Krafts leave a thin, gossamer-like, grey ash, while imitations leave a stiff, felty, dark ash.

Greaseproof paper may be tested by the application of oil of turpentine. If really greaseproof, the oil remains on the surface, but, if imitation, a stain will rapidly appear on the under-side.

Genuine vegetable parchment may be chewed for some time and still retain its structure, whereas the imitation product would be reduced to a pulpy mass.

Pasteboards are identified by the dark coloured inner substance revealed on tearing. Pulp boards show the same colour throughout and have a clear look-through. Ivory boards are much stiffer and harder and clear and translucent in the look-through. Wood-pulp boards are of a coarse quality and soft texture, creamy or yellowish in appearance and entirely lacking in strength. Chiefly used for packing and lining purposes it is merely necessary to describe them in order to avoid confusion with fine pulp boards on account of the close similarity in the descriptive terms.

APPENDIX

FIRE HAZARDS OF PAPER MILLS

By Robert Taylor, F.C.I.I.

It is not unusual as an introduction to a review of the fire hazards of a particular industry to describe in more or less detail the raw materials used, the processes and machinery of manufacture, and the varieties of the finished product. But in this appendix to the handbook on *Paper and Paper-making* such an introduction is unnecessary. The handbook itself covers this ground in considerable technical detail so that it will only be necessary, as the fire hazards of the industry are discussed, to supplement the details of materials and processes and finished products already given, so as to illustrate certain points in this review of the fire hazards of the paper industry.

The first fact to note in regard to the fire hazards of paper mills is that the hazards do not arise so much from the materials used in the making of paper or from the processes carried on, or from the finished product, but are what, in insurance parlance, are called common hazards.

The second fact to note in regard to the fire hazards of paper mills is that these common hazards mentioned in the last paragraph derive a special significance from the nature of the paper mill risk.

Paper mills are usually a series of buildings in open communication from end to end without any adequate cut-off, so that entering such a risk, through a raw materials store, and observing the preliminary processes

of picking, sorting, cutting or chaffing, willowing and dusting in respect of rags, or the same processes except picking in respect of wastes, ropes, and tarpaulins, etc., or of willowing in respect of esparto, it would be possible to follow in sequence the main processes in paper-making from boiling, breaking, and washing and beating to the stuff chests and paper-making machines, and even to the "salle" where finishing and packing and storing are done. This free communication between buildings comprising a paper mill—accentuated sometimes by the hazard of a rope race—and aggravated by ceilings and linings of wood and wooden partitions, is responsible for the heaviness of paper mill fires. Possibly near to one of the buildings or to a railway siding, esparto or wood-pulp (which is really half-stuff) would be seen in the open. Even wood-pulp in the open will burn—one such fire entailing a loss of £5,000 on wood-pulp is recorded, the fire starting in a paper-coating machine-room.

The paper mill risk, therefore, furnishes as characteristic an example of a certain type of accumulation hazard as may come within the compass of an insurance man's experience. This accumulation hazard is accentuated in many cases by the hazard of defective construction. It is important therefore to observe what is the proportion of timber in the construction of the buildings comprising any mill, and what is the cubical capacity of the whole range of the buildings.

Separation of the raw materials stores and of the sorting, chopping, and willowing house from the remainder of the mill by double fireproof door communication, or if possible by fireproof passage with fireproof door at each end, should be required. Every insurance man can recall cases where on the occasion of a fire when a mill was standing, fireproof doors which should have

been shut were disclosed by the fire to have been open, and if the fireproof doors are not automatic in their action it is well to ascertain what provisions are made for closing them when the mill is standing. Some doors which should close automatically are deliberately fastened up so as to be kept open, or without thought are prevented from closing through materials being left in the doorways. But even when a risk is of good construction, and the raw materials stores and preparatory section of the risk is cut off from the remainder of the mill, such arrangements may all be of no avail because of the situation of such a risk.

Water of good quality and to be had cheaply is essential in paper manufacture, and paper mills are mostly to be found in country districts. The situation may therefore be exposed, and the raw materials stores and preparatory section should, if possible, be placed in the quarter from whence comes the less prevailing winds. But, of course, paper mills are not designed from the point of view of fire hazards, but with an eye to convenience in working and the location of the more hazardous sections of the risk will be influenced by road or rail or water facilities. Many mills are miles from any town or city fire brigade. In isolated districts, therefore, it is imperative that there should be available fire extinguishing appliances really effective and kept in good order, with men regularly drilled in their use.

Attention has already been drawn to the fact that the fire hazards of the paper mill are not so much trade hazards as common hazards, and fire insurance experience in this class of risk disturbs the natural grading of these common hazards which might be made without regard to any particular class of risk. From an analysis of the causes of fire in paper mills, one can determine which common hazards are most to be feared in such

risks. The causes of nearly half the fires are unknown, and all one can do is to ascertain the point of the risk where such fires began so as to determine the probable cause of fire. Fires appear to be equally distributed between day and night, so that the night-work hazard in a paper mill appears to be negligible. They are more common in summer than in winter, so that the hazards of heating and lighting would appear to have less than their usual significance. Fires on Saturday and Sunday are more serious than at any other period of the week, which would seem to suggest that any incipient fires are not then so readily detected, or that in the urgency of repairs usually carried on at such a time risks are incurred which are greater than those existing during the remainder of the week.

Experience shows the most serious causes of fire to have been three—

(*a*) Carelessness of workpeople,
(*b*) Friction,
(*c*) Spontaneous combustion,

and where the cause of a fire is unknown the points of the risk at which the fire started, taking the fires in the order of their seriousness were—

1. Salle.
2. Wet process rooms.
3. Power house.
4. Subsidiary buildings.
5. Machine house.
6. Raw materials stores.

These fires where the causes are unknown, confirm the fact with regard to paper mill fire hazards with which we started, namely, that the hazards are common hazards rather than trade hazards. The most hazardous group from the point of view of trade hazards, namely, the dry preparatory process group, does not appear on

the list at all, and the group responsible for by far the most serious fires is the salle—other groups being wet manufacture, power, subsidiary buildings, and paper machine house.

Accepting the definition of Common Hazards appearing in the current syllabus of The Chartered Insurance Institute, these might be said to include hazards arising from defective construction, exposure (including areas), height, floor openings (hoists, stairs, wells, trap doors and the like), linings to walls and ceilings, partitions, lighting, heating, ventilation, power (boilers, engines, dynamos, motors, gas plants, and the like), cubical capacity or hands, night work, plural tenure, storage of hazardous goods, spontaneous combustion, non-removal of waste.

Practically all these hazards except, perhaps, height and plural tenure, arise in a paper mill risk, but having regard to the known causes of fires and to the point of origin of fires where the causes are unknown, and to the spread of fires in paper mills, the attention of the surveyor would be directed to defective construction, exposure, openings, wood linings and partitions, etc., cubical capacity and night work (already referred to), lighting, heating, ventilation, power, hazardous goods, spontaneous combustion, non-removal of waste, but above all to the question of management.

The last-mentioned being so all important may be referred to first. The most serious known cause of fires is declared by Mr. John Dobson in his paper on "Paper Mills," in Vol. 17 of the *Journal of The Chartered Insurance Institute*, to be "careless use of lights, lamps, and torches," which involves management and suggests a lack of adequate control.

Management is also involved in the next most serious cause of fire, namely, friction in shafts and bearings.

The quality of oil used in lubrication, the frequency or infrequency of lubrication, and whether bevel wheels are enclosed in metal and drip pans are provided for oil droppings must all be considered. This matter is of special significance, because of the speeding-up which has taken place in all machinery used in paper-making. Paper-making machines, even a dozen years ago, were advertised to make paper on wire 175 in. wide, and to run at a speed of 600 to 700 ft. per minute as against a speed of 200 to 300 ft. prevailing some 40 years ago.

Cleanliness is also a matter of management, and involves the clearing out of all waste, including "broke," i.e. damaged or waste paper, regularly: the cleaning down of all rooms, such as raw materials stores and the sorting, chopping and willowing house where dust may accumulate, and the keeping as low as possible of the supplies of raw materials in the boiling house.

Spontaneous combustion in rags, ropes, etc., and esparto, the third most serious known cause of fire, is also a matter of management, and raises the question as to whether adequate care has been taken in the storage of these materials. If some of the materials are wet and under heavy pressure the risk of spontaneous combustion is increased: and care should be taken in the use of naked lights.

Lighting requires special attention particularly in the rooms already referred to in which dust may accumulate, and lights used in making repairs require perhaps even greater attention.

The hazards from heating may arise from hot water or steam pipes, which should be kept clear of wood-work and other combustible materials. If materials, such as paraffin wax or resin, incidental to certain processes in paper-making are heated, attention must be directed

to the construction of the heating apparatus, and adequate precautions should be taken as to its use.

As regards power, attention must be directed to the engine house, even to a water turbine house as well as to the boiler house, where risks in drying sometimes exist.

In the making of certain fine art papers drying will require special attention. Rolls of paper are hung festooned on poles, and in such a room lighting should be by incandescent electric light, and care taken that the paper rolls are kept clear of the heating pipes.

Lighting and heating used in the packing rooms should also receive attention.

The hazards of raw materials used in paper-making have already been mentioned as also certain other hazardous goods incidental to the process of paper-making, so it only remains to name other hazardous goods which may be used in the making of certain specialities in paper or incidental to paper-making, such as solvents where coloured paper is made: lime in the making of animal size, varnish, sulphuric acid for the dipping of parchment paper, linseed oil and benzine in the making of tracing paper, stearine and paraffin wax in the making of carbolic acid paper, and lard, lard oil, lamp-black and tallow in the making of carbon or transfer paper. Care must be taken in the storage of these hazardous goods, and only sufficient supplies as are required for immediate use should be brought into the mill. Special care in the lighting and heating arrangements are necessary where a volatile spirit, such as benzine or lamp-black, which is subject to spontaneous combustion, are used.

Paper mills are broadly divided into two classes: "brown" and "white." The former are regarded as more hazardous because of the materials used and the

nature of the paper produced, but the experience of them is more favourable than that of " white " mills, no doubt because the mills are smaller as a rule and there is, therefore, less value at risk. Among " white " mills the largest group is that where printing and newspapers are produced, and that is also the heaviest class from the fire loss point of view. The next largest class is that producing account and writings papers, and following close is the class producing mixed account writings, printing and newspapers. The loss experience in these two latter classes is much the same.

Among subsidiary buildings the soda recovery plant is the most notable, and this is usually detached from the main risk and often of more solid construction than the main risk itself, and not requiring special attention from the point of view of fire hazards.

The risk of explosion is one which might not be expected to be found in a paper mill, but experience shows that it exists. Dust, especially carbonaceous dust, is a fruitful medium of explosion. Dust is, of course, inevitable where raw materials are stored, or where sorting, chopping, and dusting of raw materials is carried on. Dust may also be produced by the grinding of the ends of paper rolls. Such an explosion mentioned by Mr. Dobson in his paper already referred to, occurred in a mill at Tourcoing in France. The dust was exhausted into a dust-room and periodically removed. On one occasion two workmen entered this dust-room for the purpose of clearing it out, and took with them into the room two ordinary square glazed lanterns burning colza oil. After work had gone on for some time an explosion occurred. Samples of the dust were sent to the analytical laboratory at Lievin, and the dust was declared to be extremely inflammable and, when blended with atmospheric air, capable of explosion if

brought into contact with a flame in a closed compartment. On the authority of Dr. Wheeler, chemist to a Home Office Committee on Explosion in Mines, two ounces of dust per cubic yard of air may flame in the presence of naked lights. The risk of explosion also exists where there is any soap recovery or soap made. Properly protected incandescent electric lights having double globes are desirable, if not essential, wherever the risk of explosion exists.

The processes of paper manufacture and the fire hazards attaching thereto were one of the subjects of examination in the Part I Fire Branch Associateship Examination of The Chartered Insurance Institute in the year 1920. Questions were asked as to the principal materials used, and as to the principal processes in paper-making: also as to the details of four named processes, namely, boiling, breaking, and washing, the paper-making machine, and calendering, and a description of the salle was required. Questions were also asked as to the distinction between a white and brown paper mill, and as to the particular hazards of each and of raw materials stores and cutting and willowing. In the Common Hazards paper of the same year, a question was asked as to the hazards in the storage of rags in a paper mill and the precautions to be taken.

If a new cellulose process being developed in Germany finds a place in this country, one may find the future paper mill combining certain insurance features of an artificial silk factory with those of a present-day paper mill. It is claimed that excellent samples of a superior white paper have been made from cotton stalks, slash from pine saw-mills, sawdust, wheat, oats, and barley straw.

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